FORESTRY

INDIANA

1907

The Passing of the Forest

As long as the forest shall live,
The streams shall flow onward, still singing
Sweet songs of the woodland, and bringing
The bright living waters that give
New life to all mortals who thirst.
But the races of men shall be cursed.

Yea, the hour of destruction shall come
To the children of men in that day
When the forest shall pass away;
When the low woodland voices are dumb;
And death's devastation and dearth
Shall be spread o'er the face of the earth.

Avenging the death of the wood,
The turbulent streams shall outpour
Their vials of wrath, and no more
Shall their banks hold back the high flood,
Which shall rush o'er the harvests of men;
As swiftly receding again.

Lo! after the flood shall be dearth,
And the rain no longer shall fall
On the parching fields; and a pall,
As of ashes, shall cover the earth;
And dust-clouds shall darken the sky;
And the deep water wells shall be dry.

And the rivers shall sink in the ground,
And every man cover his mouth
From the thickening dust, in that drought;
Fierce famine shall come; and no sound
Shall be borne on the desolate air
But a murmur of death and despair.

—Alexander Blair Thaw, in the June Century.

STATE OF INDIANA

SEVENTH ANNUAL REPORT

OF THE

State Board of Forestry

1907

W. H. FREEMAN, Secretary

To the Governor of Indiana

INDIANAPOLIS:
WM. B. BURFORD, CONTRACTOR FOR STATE PRINTING AND BINDING.
1907

THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
December 9, 1907.

Received by the Governor, examined and referred to the Auditor of State for verification of the financial statement.

OFFICE OF AUDITOR OF STATE,
INDIANAPOLIS, December 27, 1907.

The within report, so far as the same relates to moneys drawn from the State Treasury, has been examined and found correct.

J. C. BILLHEIMER,
Auditor of State.

DECEMBER 27, 1907.

Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.

FRED L. GEMMER,
Secretary to the Governor.

Filed in the office of the Secretary of State of the State of Indiana, December 27, 1907.

FRED A. SIMS,
Secretary of State.

Received the within report and delivered to the printer December 28, 1907.

HARRY SLOUGH,
Clerk Printing Bureau.

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Illustrations

Indiana State Board of Forestry

OFFICIAL MEMBERS, 1907.

FINLEY C. CARSON, President	Michigan City
STANLEY COULTER	Lafayette
LARKIN M. STULTZ	Westfield
SAMUEL BURKHOLDER	Crawfordsville
WM. H. FREEMAN, Secretary	Wabash
AMY STOOPS, Stenographer	Wabash

Office of Secretary.

Room 93, State House, Indianapolis.

STATE OF INDIANA, BOARD OF FORESTRY,
INDIANAPOLIS, IND., December 1, 1907.

HON. J. FRANK HANLY, *Governor:*

Dear Sir—In compliance with the legal requirements, we have the honor to submit herewith the manuscript of the Seventh Annual Report for the Department of Forestry. It contains papers of discussion and explanation of the various work accomplished by the office and of experiments and forestry work at the State Forest Reservation and Forestry Experimental Station at Henryville, Clark County, Indiana.

We express our sincere appreciation of your courtesy and cooperation in the cause represented by this Department, and feel that the subject of forestry and the work accomplished should receive from the people an intelligent and thoughtful observance as affecting the best interests of all.

Yours very truly,

F. C. CARSON, President.

W. H. FREEMAN, Secretary.

Preface

The subject of forestry in all its various features has received as much intelligent thought and consideration the past year as any other one current movement affecting the general welfare. The most thoughtful people throughout the land are according to it their high appreciation.

It is not easy to state the exact accomplishment in the work because of inadequate means to secure data and co-operate closely with the forestry communities. Not sufficient funds are provided the Board for its systematic organization of the work throughout the State by counties or districts. The actual office expenses by reason of correspondence, arrangement and distribution of good forestry literature and other educational features, as lectures and travel, demand all the funds provided. The financial equipment of the office does no more than provide for these details well in conjunction to the office expenses of the Reservation and Experimental Station. Under the present conditions something must be neglected and it has been the systematic organization of the forestry work in the counties and data pertaining to them. Provision must be made for a competent assistant in the office and his expenses to do these things before the office can perform its duties fully and well.

As was suggested in the last report more power should be given the Board for the control of shade and ornamental trees growing along the highways and in the cities and towns against linemen. This was attempted during the last session of the General Assembly, but all was lost because of the radicalism in the bill attempted, and because at an unguarded moment the modified bill was killed on its final reading by an enemy or the accomplice of an enemy to the movement to protect such property and accord to it an intelligent regard and ownership right. The Board hopes for a concerted action to gain this needed regulation at the hands of the next General Assembly. But whatever is attempted must be intelligent and contain equal rights to all parties concerned or failure will be the result again.

The experiments at the Forestry Experimental Station are ad-

vancing very satisfactorily and at this early date are evidences of what the success of forestry may be to those who engage in it. The work now accomplished shows what practical things in forestry may be done if only attempted. As an object lesson versus theory, it may be acknowledged far beyond expectations and general belief in the degree of success. The tabulations given in the report convey an idea of the advancement of the experiments, and as years go on they will without question become more and more convincing and prove to the unbeliever the value of the institution. As an object lesson of merit it receives the highest praise from forestry students and experts, and as a property of value it meets the mind of the confident business man who can discern the distant aggregates. It is an example of doing things as against talking about doing them, and therefore appeals to good judgments.

The Board sincerely appreciates the great influence of the press in the educational formation of a right forestry sentiment, and urges that the same keen interest and devotion of the past be extended in the future. The various literary and civic federation clubs have added much to the increased interest and advancement of the forestry movement. To them also the Board expresses its esteem and urges them to greater achievements in the work of the civic principles, "cities beautiful," but warns them against radicalism as suggested in the discussion of needed legislation. Intelligence, fairness and equal rights to all interested should characterize every step taken in the advancement of the cause of forestry.

The "farmers' institute," that grand organization for the promotion of agricultural interests, should do more to influence the forestry cause than it is. By reason of the plan and manner in which it is organized and conducted, it could be made a factor equal to the public press in the formation of a right forestry sentiment and the Board suggests that it do more toward advancing this worthy cause.

BOARD OF FORESTRY.

Financial Statement

November 1, 1906, to September 30, 1907.

Appropriations to November 1, 1907, by Acts General Assembly, 1905—

1. Office—	
Salary of Secretary of Board	$1,800 00
Salary of stenographer of Secretary	600 00
Salary of four Board members	400 00
Mileage of four Board members	94 76
General expenses	1,000 00
Total	$3,894 76
2. Forest Reservation and Experimental Station	$3,000 00
3. Specific—Improvements—	
Forest cultivation	1,800 00
Field planting	720 00
Field cultivation	900 00
Building N. W.	450 00
Building S. C.	550 00
Appropriations by General Assembly 1907 and available by emergency—	
Specific—Improvements N. E.	1,200 00
Total specific	$5,620 00
Total of all appropriations	$12,514 76

EXPENDITURES.

Office—Salaries:	
W. H. Freeman, Secretary of Board	$1,650 00
Amy Stoops, stenographer to Secretary	550 00
Finley C. Carson, Board member	91 67
Finley C. Carson, Board member, mileage	45 80
Stanley Coulter, Board member	91 67
Stanley Coulter, Board member, mileage	12 72
Larkin M. Stultz, Board member	91 67
Larkin M. Stultz, Board member, mileage	16 76
Samuel Burkholder, Board member	91 67
Samuel Burkholder, Board member, mileage	19 48
Total	**$2,661 44**

Office—General Expenses:	
Mileage	$190 60
Postage	260 00
Field work	175 00
Telephone tolls and rents	87 75
Expressage	11 28
Livery hire	93 55
Office supplies	20 50
Hotel expenses	78 20
Total	$916 88
Overdraft, remitted to Treasurer	21
Reservation and Experimental Station Expense Fund—	
Management	$723 09
Labor	1,982 97
Equipment	175 63
Total	$2,881 69
Improvements—Specific	4,673 48
Total of all expenditures	$11,133 49
Balance unexpended	1,381 27
Total	$12,514 76
Receipts from Forest Reservation and Experimental Station and remitted to State Treasurer upon recommendation of State Auditor—	
Sale of fuel	$1,096 95
Sale of lumber	29 33
Sale of cross ties	159 69
Sale of shingle blocks	3 25
Sale of hoop poles	7 50
Field rents	45 85
Labor by team hauling	2 00
Total	$1,344 57

Office Report and Suggestions

The work which the Board has attempted to advance in forestry from the office the past year has been along the same lines as of former attempts. The efforts were directed toward stimulating systematic work throughout the agricultural communities by the establishment of permanent woodlots upon each farm, the increasing of interest in commercial plantings of large areas upon the cheap, non-agricultural lands, Arbor Day and general ornamental tree plantings, fencing posts and cross-tie plantings, timber and tree diseases and affections, and advice as to the best economic disposition of merchantable timber.

In results each and all the features attempted to advance, as well as the general inquiry and correspondence, show a far better intelligence and thought than were evident of previous years. Everything indicates a rational appreciation of the subject, its necessity and a desire to aid the cause by the best people.

The field work conducted by the office the past summer, with the aid of the forestry students, Fred A. Miller of Purdue University, and E. E. Davis of Wabash College, was of two distinct classes. Mr. Miller's work is shown by the report which he rendered the office and published herewith. The report contains full explanations and will not be discussed here. The work of Mr. Davis was confined to taking statistics of forest growth upon the experimental plats at the Forest Reservation and Experimental Station, to get before the readers some facts for consideration.

Both of these gentlemen are students of forestry and their services were most valuable for the brief time they were employed. The only regret is that means will not permit of constant work along these lines throughout the State and for the entire year. Such work is of the most practical value to everyone interested, whether producers or consumers.

The office feels that it is time now to begin more of the scientific features and investigations and in the future it shall do so. In the past almost all the efforts have been directed toward the promotion of tree planting and cultivating woodlots as above enumerated. It does not mean, however, to cease its efforts in these directions, but to continue them at a greater effort and add thereto the science features.

Throughout the work of inquiry, correspondence and lecture work the aim has been to show that forestry has for its foundation the industrial welfare to as great or greater extent than any other feature of general interest now before the public mind. There is not an issue of any publication for general public reading but what is more or less filled with articles treating of some of the phases of forestry and their bearing upon some vital public interest. There is no one question of public interest more fully discussed and collaborated.

The Board fully appreciates that forestry advancement in Indiana can only be a successful accomplishment by the thorough education and the formation of a new mind. For more than a hundred years in Indiana the minds of the people have been directed toward removing the forests from the land in order to devote the soil to intense agricultural pursuits. The forestry movement is the natural outgrowth of the too persistent effort to clear the land for agricultural purposes, with no thought of a future consequence. Before a successful forestry movement can be established a new mind must be formed. There must be a facing about and a marching in the opposite direction. This can only be accomplished by the education of the generations to the realization of such facts. It will take time to do it. All the efforts, therefore, of the Board are directed to accomplish this aim. Legislation and guardianship can be but elementray factors to this end.

The number of inspections and recommendations made from the office the past year were greater in number than of any former year and were of a better grade, being mostly for farm woodlots. The requests for advice for fencing post plantings continue to be sought extensively, and indicate that Catalpa Speciosa and Black Locust for consideration in planting are equally valued. The sales reported by nurserymen indicate that throughout the State these trees are being planted in large numbers.

As stated in last year's report, a closer systematic organization of the work by counties is necessary for the better doing of the work. The Secretary, in addition to the office work, is superintendent of the work of experiments at the Forest Reservation, and cannot do as close work in the counties as is needed. An assistant for such work must be secured. Much good work is done, but advice is by correspondence instead of personal visits, and frequently not all the facts are known and the best results are not reached in the community.

The Board feels, however, that actual facts for data from things

done at the Reservation will go further as evidence and will be of more value in the future to stimulate forestry than anything else, and it so directed its efforts there the past year, and it trusts the future results will bear out the policy. No other current topic before the people is as much discussed and written upon as forestry. It is a subject also having less intelligent criticisms but as many isms of aerial magnitude as any, and it behooves seekers of wisdom and truth to be cautious as to the plans and policies adopted in their forestry conduct. No State in the Union has produced a better quality and quantity of hardwoods than Indiana. Her lumber and the finished products from the same have at all times been upon the pinnacle of commercial value. The past is the best guide to the future. What Indiana has produced she can reproduce, and every evidence goes to show that Indiana's soil will naturally produce trees if only encouraged to do so, and that its tendencies are to reforest with the valuable hardwoods most abundantly. In view of all these facts the Board suggests to those desiring to grow trees to stick to our native kinds and turn a deaf ear to experimental trees, unnatural and unacclimated to our State conditions, until fully satisfied, after diligent inquiry, that they will give good results, and the evidence can be shown.

LETTER OF TRANSMITTAL.

INDIANAPOLIS, IND., September 7, 1907.

Indiana State Board of Forestry:

Honorable Sirs—I have the honor to submit herewith, subject to your approval, a report compiled during the months of July, August and September of the present year, upon "Various Forest Conditions," as studied throughout the State of Indiana. The drawings and photographs accompanying same are deemed necessary to the better understanding of the report.

The time spent under salary was the months of July, August and the first week of September; seven weeks of which were consumed in actual field investigations, and three weeks in preparing drawings and compiling complete report.

The total territory investigated consisted of nine counties, located in northern, central and southern Indiana, respectively, as follows: Starke, Marshall and Kosciusko; Clinton, Howard and Grant; Orange, Martin and Washington.

Two weeks were spent in each of the above named localities, or on an average of four days in each county. This was indeed a

short period of time in which to cover a county with any degree of thoroughness, and in fact, it could not be done. Many times the progress of the work was exceedingly slow and retarded by the many and varied conditions presenting themselves, where the report had to include such a wide range of observations. The remaining week of field operations was devoted to obtaining photographs of private forest plantings in the regions surrounding Fort Wayne and South Bend.

I wish to express my appreciation of the favors shown me by your Secretary, W. H. Freeman, and also to say that the work now being carried on, not only upon the Reservation but throughout various parts of the State, cannot be too highly commended, or too strongly encouraged.

I would beg to be corrected for any statement contained herein to which you may object.

Respectfully,

FRED A. MILLER.

INTRODUCTION.

The contents of this report will be found under two distinct and separate heads: (1) Insect Pests of Indiana Timbers and Timber Trees; and (2) Growth and Development of the Oaks, Hickories and Ash, as Influenced by Soils and Other Important Ecological Factors.

The need of the investigations included under the first head was suggested by the ever-increasing demand for structural timbers and timbers used in many of our leading industries. That the supply of such stock is daily decreasing is acknowledged by all; and in this early stage of the forest policy, everything possible is being done by both national and state governments that this condition may not long continue. Special attention is being given to a determination of the most suitable localities for forest plantings, in order that this end may be most surely and quickly attained.

Natural reproduction and development are essential to the success of such plantings, and localities must be well chosen, that growth may be most rapid and vigorous. See figure 30 for results of a poorly chosen locality on which to plant black walnut. The spoke factories of our southern counties present one of the most glaring examples of the serious condition of one of our most valuable native trees. Already these manufacturers are anxiously discussing the possibilities of the next "cut" of second growth hickory, with which their mills must be constantly supplied. Natural reproduction of the hickory, especially the shellbark, is known to be

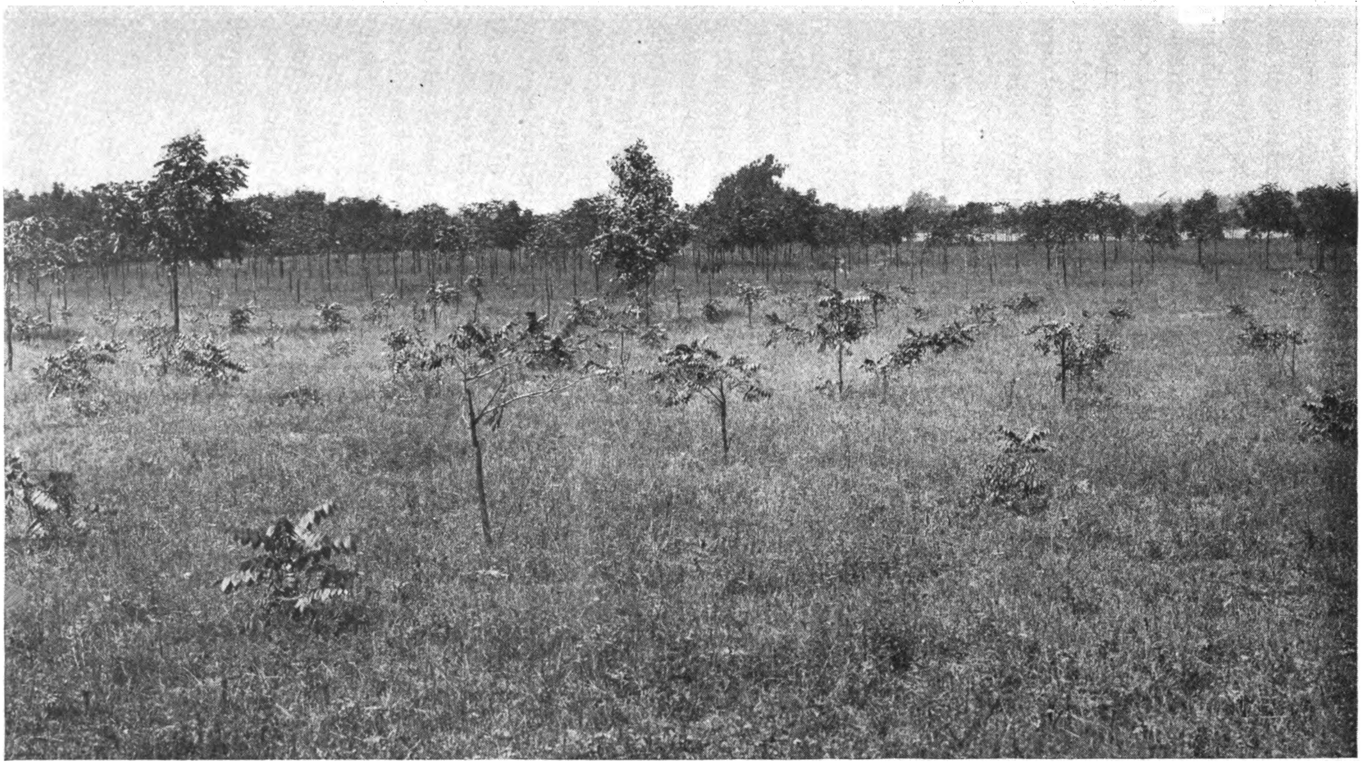


Fig. 30. A more general view of same planting as shown in Figs. 28 and 29. A more striking example of unevenness in growth and almost complete failure from soil conditions could not be obtained.

exceedingly slow, and the supply will continue to fall short of meeting the local demand, unless present conditions are immediately altered. Extensive plantings and conservative cutting of the present stand seem to be the only presentable solution. The many acres of absolutely waste and otherwise worthless land of southern Indiana are the most ideal and in every way the most suitable places for such undertakings. But that such plantings should succeed to the best possible degree, keen discrimination must be made in the selection of suitable localities with regard to soil conditions and other modifying elements. The owners of these waste lands must be appealed to and in some way influenced to such a degree that problems of this kind will be undertaken by them.

The contents of this section of the report consists of a setting forth of facts of a general nature, and in language readily interpreted by the layman, which should in part enable him to keep his waste land covered with the most rapidly growing and most profitable species of our valuable forest trees.

The first part of the report, "Insect Pests of Indiana Timbers and Timber Trees," was suggested by the ravages of many wood-destroying insects, upon our forest trees, some of which are active for a considerable time during each succeeding year, and others of which only make their appearance at irregular periods, leaving their destructive work as the only evidence of their existence.

Recent investigations have shown that oaks, chestnut, hickories, maples, birches, walnuts, cherry, poplar, gums and other of our principal hardwood, or broad-leaved, timber trees are damaged to a far greater extent than is realized by the casual observer. A large percentage of the hardwood timber in nearly all of the States east of the Rocky Mountains is affected, and the United States Forest Service states that the average annual losses from this source could be safely estimated at between fifteen and twenty million dollars.

Insects not only cause a direct loss to the owners of forests, manufacturers and consumers of forest products, but by their continued depredation constantly and surely contribute to the rapid depletion of all hardwood timber forests of the country.

INSECT INJURIES TO FOREST TREES OF INDIANA.

The primary objects of this investigation were (1) to determine the comparative extent of injury to native trees and some of their products and the kinds of insects causing such injury (2) to determine, when possible, some practical method by which to prevent to some degree the annual losses of valuable timber, from this cause.

It is aimed in this report to give a short and concise account of the results of the investigation with recommendations of such methods of prevention or control as seem of a practical nature.

THE CHARACTER OF INSECT INJURIES TO FOREST TREES.

The character of insect injury to forest trees may be treated under two distinct heads:

(1) Injuries which cause the death of trees.

(2) Injuries found in the solid wood which do not immediately result in the death of the trees, but cause serious defects in the parts of the tree, which furnish materials for commercial products.

There is also considerable loss experienced from insect injuries to felled trees, saw logs, ties, posts and many other crude products, which will be discussed briefly.

KNOWLEDGE NECESSARY TO PREVENTION OF LOSSES.

In dealing with insects, the methods which always produce the best possible results are those which relate to preventing attacks. Before preventive methods can be applied, however, a complete knowledge of the insects causing the injury, as well as the conditions most attractive to them, is absolutely necessary.

Insects in general have two objects in their attack; one is to obtain food, the other is to prepare for the development of their broods. Different species have special periods during the season of greatest activity when the adults are on the wing searching for suitable places in which to deposit their eggs. Some species fly in April and attack only recently felled pine trees. They are not attracted to any other kind of timber, because they cannot live in the bark or wood of any other tree, and only in such pines as are in the proper condition for hatching their eggs, and favoring the development of their young. There are also forms which attack only oak trees; others infest only hickory, and so on for many classes of trees.

Each of these forms possesses different habits, and has different periods of flight, and requires special conditions of the bark and

wood for its development. Some have but one generation in a year, others have two or more, while some require more than one year for the development of a single generation. Some species deposit their eggs in the bark or wood of trees soon after they are felled; others are attracted only to dead bark or wood of trees which have been felled or deadened for several months. Other variations in season and special conditions are noted, and it is easily seen how important it is to have a knowledge of such of the foregoing facts as is possible in order to meet the requirements necessary for preventing losses.

INJURIES WHICH CAUSE THE DEATH OF THE TREE.

The most important insects which cause the death of forest trees of the broad-leafed type are those which burrow through and beneath the living bark of the tree. There are two distinct classes of these injuries, one caused by the bark-boring beetles, the other by bark-boring larvae or grubs. The adults of this class of insects bore into and beneath the bark for the purpose of excavating galleries in which to deposit their eggs. These galleries are the primary injury which weakens to some extent the vitality of the tree, while the secondary or larval mines (see Fig. 1) complete the

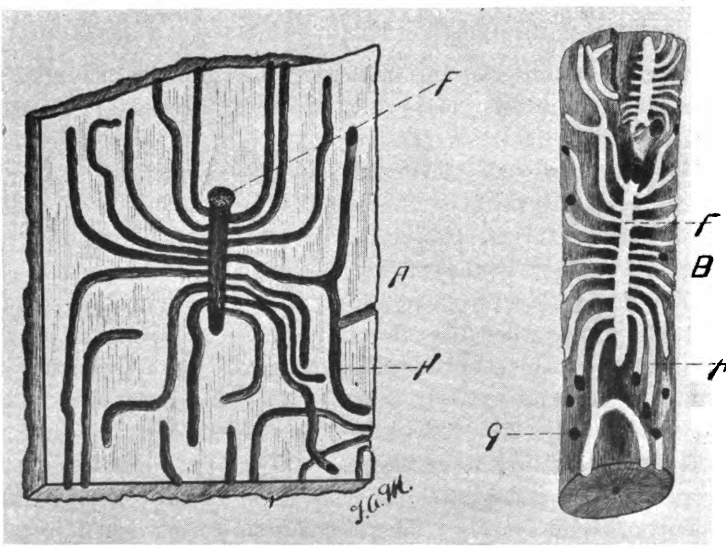


Fig. 1. Work of the Hickory Bark-Beetle: A, inner surface of piece of bark taken from dead tree; B, section of dead limb; F, primary gallery; H, larval mines; G, exit holes from which broods of the Bark-Beetle have emerged. Drawings from specimens collected three miles northeast of Marion, Grant County, Indiana.

girdling process which completely deadens the tree. The injuries from bark-boring grubs are the work of larvae which hatch from eggs deposited by the adult insect in the outer dead bark, and never in burrows beneath it. Therefore, the burrows made by the young larvae through the living inner bark, in search of food, not only cause the primary injury, but also complete the deadening process.

INJURY TO HICKORY TREES BY BARK-BEETLES.

Considerable attention has been directed to this form within recent years on account of the many dying hickory trees. This has been especially true in the northern and central States. The trouble has been reported and the damage found to be extremely noticeable as far south as central Georgia and westward to Missouri. Thousands of scattered trees have died, and in some sections nearly all of those in forests, parks and farm woodlots have either perished or been seriously injured. This injury is causing a great loss, not only of a valuable timber tree, but of shade trees, and especially is it causing a rapid decrease in the crop of nuts, which latter, in some sections of the country, are of considerable importance. This importance extends not only to the commercial product and home consumption, but also influences the natural reproduction of this form and so to a degree determines the future state of our hardwood forests. The dying of the hickory trees has been found in nearly every case investigated and reported upon, to be the direct result of injuries to the buds and twigs and to the bark of the branches and trunks by the bark-beetle (Scolytus 4 spinosus).

THE HICKORY BARK-BEETLE.

The hickory bark-beetle, or engraver beetle, is a short, shining black or reddish brown beetle, averaging about .14 of an inch in length. The wing covers are short and project over the abdomen, which in the male is excavated beneath and armed with four somewhat prominent spines, which suggest its technical name. It flies about from May to August and generally begins its attacks on the living trees at the base of the buds and leaves. Injuries of this nature were noted in two localities in northern Indiana during the latter part of July. Many twigs had been injured just back of the terminal bud, and as a consequence many of these buds were dead. Also many twigs and even small branches were showing the effect of this early attack. In another instance a small grove of second-growth hickory was examined where this same injury was interfer-

ing seriously with the development of the young trees. The injuries in both of the above-named cases were confined to the young and more tender parts of the trees, and at this early stage of the season were apparently a result of the insects' efforts to obtain food. Later they enter the bark of the larger branches and top of the trunks and begin excavating short longitudinal burrows (Fig. 1, F) in the inner bark and surface of the wood. The eggs, which are placed along the sides of these primary galleries, hatch into small white grubs or larvae, which burrow at right angles through the inner bark and groove the surface (Fig. 1, H) of the wood to some extent. The broods of larvae pass the winter in these brood galleries, and transform to the adults in the spring, in the outer portion of the inner bark. These adults emerge through holes bored through the outer bark (Fig. 1, G) to continue their work on the buds, branches and remainder of the trunks that were not killed by the first attack. In this locality they begin to emerge about the first of June and many individuals of the brood continue to emerge until late August. They may be found depositing eggs as late as September and are thus found attacking trees all through the summer.

The first evidence of an attack is generally shown by the leaves, some of which die and remain on the twigs, while others fall early. Late in July and especially in August, the large branches in the top of the tree begin to die and in some cases the entire tree is killed the first season. More often, however, the lower portion of the large tree does not die until subsequent attacks are made upon it. Upon removing the bark from some of these injured parts the characteristic brood galleries will be found in the inner bark and to some extent on the surface of the wood (Figs. 1 and 3). If the tree is infected, the parent beetle will be found in the primary longitudinal gallery, and many of the small, white grubs in the larval burrows in the bark. If the broods have emerged, the outer dead bark will be found perforated with numerous small round holes, as indicated in Fig. 1, G.

Damage from this destructive form was found to be most extensive in the central portion of the State. In Howard County, examples were found where trees ranging from 10 to 18 inches in diameter were in various stages of destruction from attacks by this form. The trunk of a dead but apparently sound tree was closely examined. The numerous exit holes of emerging broods aroused suspicion, and upon removing portions of the bark the cause of the tree's death was unmistakable. The inner bark was

reduced to a powdered condition by the brood galleries and extensive larval mines which extended entirely around the tree and as high up on the trunk as a man could reach.

The extent of the loss from this insect, in central and northern Indiana, is limited to a large degree by the scarcity of hickory. Should the form spread to southern counties, however, the loss would be considerable. Consequently, all possible means should be taken to confine the injury to the smallest possible territory and to keep it from entering the larger stands of hickory.

METHOD OF CONTROL.—A peculiarity in the life history of this form makes it a comparatively easy pest with which to deal. In this locality there is but a single generation annually, and the immature stage of the generation passes the winter in the bark of the infested trees. These are two facts which assure its easy destruction, since it is only necessary to determine the trees which are actually infested, at the beginning of winter and to be sure that these are all cut and the bark burned before the first of the following May. June was stated as the time when the brood emerges in this State, but this date varies considerably, according to conditions, and it would not be considered a safe plan to delay such treatment longer than the first of May. If the greater number of infested trees over a considerable area are thus treated, the number of insects will be so reduced that they cannot continue their destructive work on living trees. It must be remembered that nothing is to be gained by cutting and burning the dead trees after the broods have emerged, but that the greatest importance lies in locating all trees which have died within a year from May or June and are infested, and that these be cut and the insects destroyed before the following spring. In many cases it would be advisable, where only the top or side branches are attacked, and the remainder of the tree living, to cut out and destroy this part and thus save the more valuable portion of the tree. The broods can be destroyed without loss of the entire tree by utilizing suitable parts for fuel or other purposes, if consumed within the specified time. When the logs are still valuable, the bark can be removed and burned or the logs placed in water until the insects are dead.

The practical application of this method of cutting and burning the infested trees was made by the commissioner of parks of Detroit, Mich., in Belle Isle Park, May, 1903. Many hickory trees were infested, and indeed all were threatened with destruction by this insect. Upon request of the commissioner, investigations were made by A. D. Hopkins of the United States Department of Agri-

culture, who recommended that the infested trees be cut and burned before the broods of the beetle commenced to emerge. This plan was thoroughly carried out and no evidence of the destructive work of the insect on the remaining trees has since been observed.

BARK-BEETLE INJURIES TO OAK.

This form is very similar to the preceding in its habits and manner of attack. It is found infesting different kinds of oaks, ranging in size from a few inches in diameter to large trees. Upon removing the bark from an infested tree the inner surface is found to be grooved with a great number of very minute transverse burrows which are also faintly marked on the surface of the wood. This form is, pityophthorus pruinosus, the beetle of which is exceedingly small. In early spring the emerging broods prefer to enter the bark of trees felled or injured by storms or other causes. If these conditions are lacking they will concentrate their attentions on a few living trees, which they soon reduce to a weakened condition.

This form was not encountered in any locality studied, but its wide distribution and the possibility of a periodic appearance justifies a brief discussion at this time.

The method of control is very similar to that employed for the hickory bark-beetle, only in this case a removal of the bark from infested parts in winter is sufficient to kill the broods. Often, however, it is easier to burn the branches and confine the removing of the bark to the trunks alone. A second generation is also possible with this insect, and trees which die early in the season should be cut and treated as above, as soon as the leaves commence to die. This will prevent the development and emerging of a possible second generation, before winter. Therefore, all that is necessary to prevent serious and extensive harm from this insect is clean forest management and prompt felling and removal of bark from dying trees.

BARK BEETLE INJURIES TO OTHER TREES.

Many forest trees, besides those mentioned, are injured by this class of insects. The great numbers of species, however, will limit their treatment, and only those forms found in the State which are of most economic importance will be considered.

Walnut was found in southern Indiana slightly injured by girdling forms. This was largely white walnut or butternut (Juglans cinerea), and the attack was generally confined to trees which had

been weakened by other agencies. The insects seemed to possess little power of gaining a foothold on healthful and sound trees. The galleries in this case (see Fig. 2) are not so characteristic of species as those on the hickory and oak. The engravings and ornamental transverse galleries are absent, and are replaced by larval mines radiating in a miscellaneous manner.

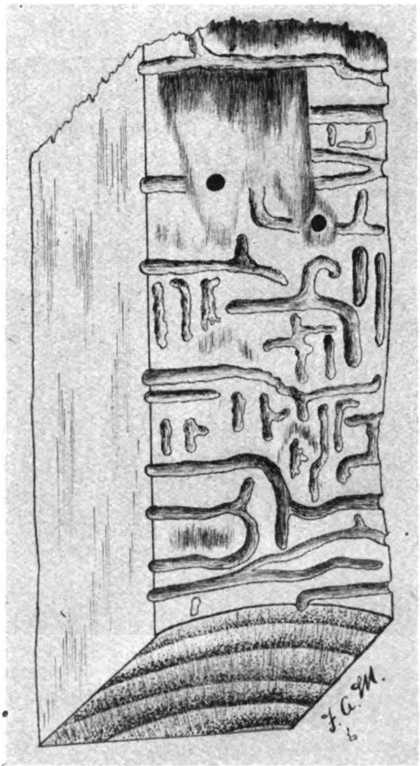


Fig. 2. Section of wood cut from a White Walnut (Juglans cinerea), which had been entirely girdled. The galleries are found in the cambium (inner bark), penetrating slightly into the sap wood, thus effectively deadening the tree. Drawing from specimen collected two miles east of Paoli, Orange County, Indiana.

The wild cherry (Prunus serotina) is sometimes seriously injured by the cherry bark-beetle (Phloeophthorus liminaria), but this insect, though capable of doing so, rarely attacks strong healthful trees. The ornamental double transverse gallery of this form in the inner bark and on the surface of the wood, is easily recognized by the characteristic form. This insect was not found in alarming numbers and loss from its attacks is, at this time, slight.

The hackberry bark-beetle (Scolytus muticus), the elm bark-beetle (Hylastinus rufipes), the mulberry bark-beetle (Phloephthorus frontalis), the ash bark-beetle (Meliobius aculeatus), (see Fig. 3), and a number of others of this large class of beetles were noted, but, though they may sometimes be quite injurious, are more often secondary enemies which infest and damage only injured or weakened trees and prevent their immediate recovery.

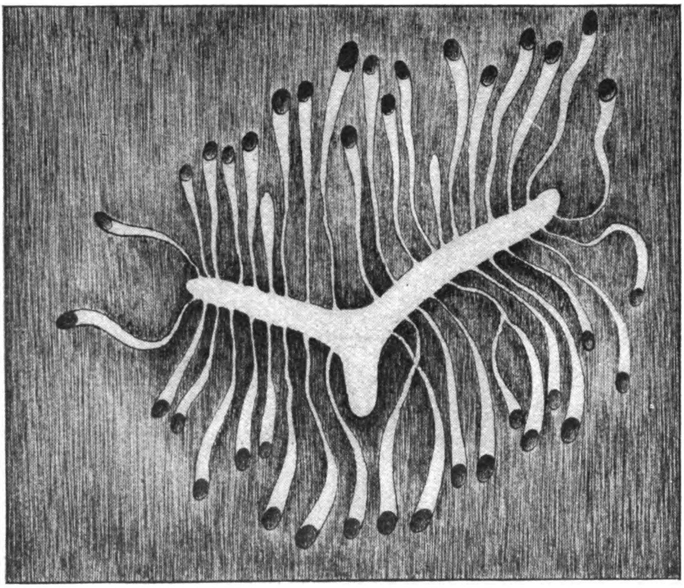


Fig. 3. Brood galleries of Ash Bark-Beetle in surface of Ash wood. From Yearbook of Department of Agriculture for 1903.

BARK-BORING GRUBS OF OAKS, CHESTNUTS, BIRCHES AND POPLARS.

Much injury to the above-named forms has been reported from surrounding regions. Indeed, for a number of years losses have been experienced from boring grubs, but no such large bodies of timber have been killed in any one year as to excite special attention. Individual trees, however, die throughout the forests every year and contribute to the annual losses. At different periods in some of the southern States chestnuts and oaks scattered over extended areas have died in alarming numbers.

Upon investigation made in different sections it was found that the oak-destroying bark-borer, or two-lined chestnut borer (Agri-

lus bilineatus), was directly associated with the cause of this wide destruction of trees.

The adult of this ravaging enemy is a slender blue-black beetle, with a faint yellow line along the middle of each wing cover. The larva is a long, slender, flat-headed grub, which, upon hatching from the egg deposited in the outer bark, burrows into the inner bark, through which it eats long zigzag mines. When this insect occurs in great numbers in a tree, the inner bark is killed and the tree readily dies. The insect passes the winter in the larval stage in the outer portion of the inner bark, where in the spring it transforms to the adult. The beetles begin to emerge in May and June. They deposit their eggs in the outer bark of living trees, or stumps of recently felled trees, oak and chestnut, or in other places where lightning and fire have made inroads for them. They are often found breeding in countless numbers in the bark of stumps, and in this manner are enabled to increase in such rapidly multiplying numbers as to enable them to attack and kill living trees.

This is a form which should be closely guarded against in Indiana forests. Especially in the southern counties where oak and chestnut abound. At present it is not doing noticeable damage to live, healthful trees, but the conditions existing in many wooded tracts visited by the writer suggest the possibility of an attack by this insect. Many scattered chestnuts which have long passed the age of maturity and are consequently decreasing in value are rapidly becoming breeding places for many such destructive forms. Not only chestnut but many other forms such as oaks, beech and maple are found in a similar condition.

METHOD OF CONTROL.—The following method of control is taken from a report of the United States Forest Service: "There is evidently only a single generation of this insect annually, and this fact, together with its habit of breeding in the bark of stumps and injured trees, and in those killed by it, with its habit of transforming in the outer bark, suggests a practical method of control. All infested stumps and dying and recently dead trees should be located before the beginning of winter, or by the first of November, in order that the infested bark may be removed from the trunks and stumps and burned before the first of April."

"Trees struck by lightning in May and June furnish favorable conditions for the multiplication and destructive ravages of the two-lined chestnut borer; therefore, all such trees, together with those dying from insect attack, should be felled during the summer or the winter following, and the bark removed and burned. Very

often such trees can be utilized for fuel, so that nothing is lost in the operation."

The cottonwoods, birches, yellow poplar and aspens are often killed or seriously injured by various species of Agrillus, which have habits very similar to and many times identical with, the above described species, and therefore require the same treatment.

The work of these insects was noted throughout the State on yellow poplar, cottonwood and some of the oaks, but in no case were they present in dangerous numbers. The curious embossed effect noted on the surface of wood which has been infested by one of these bark-boring insects is the result of healed-over grooves made by larvae in the outer layers of wood beneath the bark. These wounds were made when the tree was in a healthful and growing condition and furnish conclusive evidence that the tree was attacked while living. The burrows are long and winding and suggest the ease with which trees are girdled and killed when thickly infested.

LOCUST BORER. (Cyllene Robiniæ.)

The economic importance of this widely-known insect as affecting the growth of the black or yellow locust (Robinia pseudacacia), is realized by everyone who is interested in this valuable tree. Private plantings as well as natural growths have been utterly destroyed or injured to such an extent that urgent need of all available information concerning the nature of its work is plainly evident.

CHARACTER OF THE INSECT AND ITS WORK.

The borer is a whitish, elongate, so-called "round-headed" grub or larva (Fig. 4, D), which hatches from an egg deposited by a black or brown and yellow-striped long-headed winged beetle (Fig. 4, C), found on the trees and on the flowers of golden-rod from August to October. The eggs are deposited in the crevices of the bark of living trees from August to October, and on hatching the young borers mine into the outer portion of the living inner bark, where they pass the winter. In the spring they bore through the bark into the sapwood and heartwood. Here they transform in July and August to pupae and in August and September to adult beetles. These beetles soon emerge from the trees and deposit eggs for the next generation of borers and beetles.

The injury to the trees (Fig. 4, A and B) consists of wounds in the bark and sapwood which, if sufficiently severe or repeated year after year, result in either a stunted growth, or the death of the

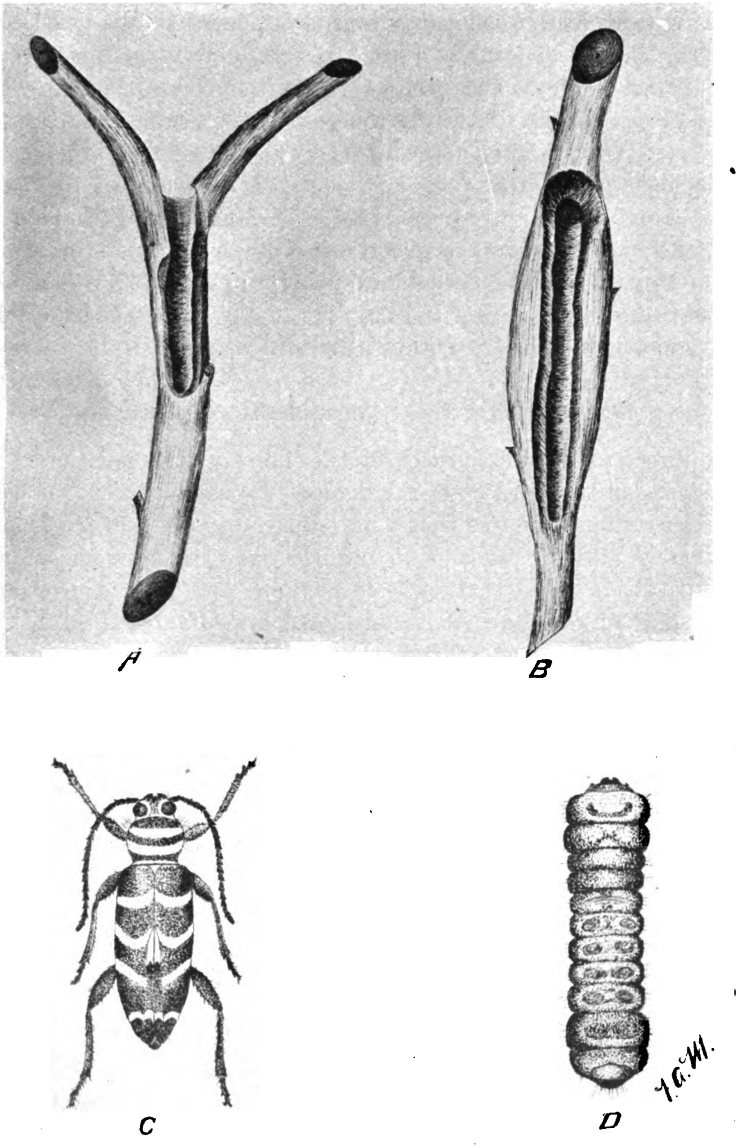


Fig. 4. Work of the Locust Borer: A, section of the main stem of a young tree, showing length of burrow in which a larva developed and transformed to the adult beetle; B, section of a branch showing enlargement at point of injury; C, male beetle; D, larvae, dorsal view. Drawings from specimens collected six miles west of Ft. Wayne, on the farm of J. H. Gerding. For photograph of planting from which specimens were taken, see Fig. 25, p. 74.

young and old trees. The numerous worm holes in the wood also reduce its commercial value or render it absolutely worthless.

The presence of the insect in injurious numbers is indicated by the frequency of the beetles on the golden-rod flowers and on the locust trees, from August to October; by the slight flow of sap and by the borings where the young larvae are at work in the bark during April and May; by the whitish sawdust borings lodged in the rough bark, and on the ground around the base of the trunk during May, June and July, and by the breaking down of the branches and young trees and by the sickly appearance of the young tender twigs and leaves in July and August.

OCCURRENCE AND EXTENT OF DAMAGE.

The insect was found in each of the nine counties mentioned in this report, and in most cases the damage from its attacks was considered injurious. It was found on both young and old trees, and so extensive was the damage to natural growths, artificial plantings, and shade trees, that in some sections, and, indeed, over the greater part of the State, it is considered unprofitable to grow the tree for shade or timber. Often in such sections the natural sprout growth is considered a pest rather than otherwise.

The loss resulting from defective timber, stunted growth, and the death of trees was found to be considerable, and could be represented by the difference in value between the damaged growth or product and the same if uninjured and healthy. It is readily seen that this, if expressed in dollars, would amount to a large sum.

METHOD OF CONTROL.—The following suggestions have been taken from various authorities and are thought to be of practical value in the control of this insect in both artificial plantings and natural growths.

The fact that the young larvae from eggs deposited during summer remain in the outer bark during the winter and do not enter the wood until the following May, suggests that if locust trees known to be infested were cut between November and May, the bark removed from that portion which is of value, and the remainder burned, it would destroy vast numbers of the insects and aid greatly in protecting the remaining trees. The infested trees may be easily detected during May, June and July by the ejected sap and borings. These trees, being once located, should be cut close to the ground and burned, before the first of August, to de-

stroy the borers before they transform to the adult beetles and emerge. The same end may be accomplished by burning the tops and worthless parts and by submerging the valuable parts in water until the borers are killed.

CEDAR BARK-BEETLE.

The cedar bark-beetle, or engraver beetle, was found in limited numbers on the red cedars of southern Indiana. The injury, so far as noted, was confined to dead or felled trees, posts which had been left in the woods, and branches of straggling young trees. In other localities outside the State this form has often done considerable damage, and is to be looked upon with suspicion, even with our limited growth of cedar.

The character of the injury is shown in Fig. 5, the specimen being taken from an infested tree near Salem, Washington county. Indiana. The specimen was collected in July and the adult beetles were found emerging at this time. The life history and methods of attack are very similar to the other bark-beetles described and will not be discussed in detail.

INJURIES TO THE WOOD WHICH DO NOT RESULT IN THE DEATH OF THE TREE.

The wood of living trees is often so injured as to not materially affect the life of the trees but to cause an enormous loss of the best hardwood timbers. This class of injuries is generally known as pinholes and wormholes. The work of these timber worms is said by some authorities to be causing greater loss than that resulting from the work of the bark-borers already mentioned. Trees attacked by the bark-borers are conspicuous and thus attract attention, while those infested by wood-borers are seldom noticed. Indeed, the damage is scarcely perceptible until the trees are closely examined or felled. There may, in fact, be hundreds of generations of this type of insects breed in and emerge from a tree during its life. The heartwood is thus rendered absolutely worthless for commercial purposes, yet the tree may continue to live and show little or no outward signs of injury. The work of these timber worms is distinguished from that of the timber beetles by the greater variation in the size of holes in the same piece of wood; also by the fact that these borings are not branched from a single entrance or gallery, as are those made by the beetles.

PINHOLE INJURIES IN OAK.

When once established in large numbers this is one of the most destructive classes of enemies of hardwood trees. The oak timber-worm (Eupsolis minuta) is the best representative of the class. This is a slender whitish worm, full grown specimens of which are less than an inch long and one-sixteenth of an inch or less in diameter toward the middle of the body, while the segments toward the head are enlarged to twice this diameter. The adult is a slender, reddish snout-beetle, with black markings, varying in length from four to six-tenths of an inch. The beetles appear on the wing in April and May, and are found through the spring and summer months on or near fresh or old wounds on living trees. They deposit their eggs in the surface and edges of these injured

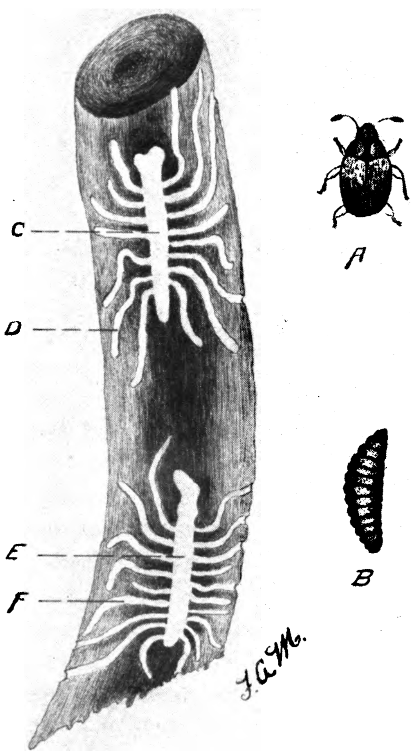


Fig. 5. Work of Pine Beetle on branch of Red Cedar: A, adult beetle; B, larva; C and E, primary galleries; D and F, larval mines made by the newly hatched larvae. Drawings from specimens collected three miles west of Salem, Washington County, Indiana. Collections made July 12, 1907.

places and the minute larvae bore, at first, almost invisible holes directly into the wood. These larvae enlarge and extend these burrows in all directions through the heartwood until they have attained their full growth. Then, while yet within their burrows, they transform to adults, to emerge the next spring or summer and repeat the process in the same wound, or in the wood of dead standing trees and the stumps and logs of felled ones. Thus, an ax wound in the side of a large sound tree may result in an attack by this insect. This form breeds in great numbers in the trunks of old dead trees and in the stumps of logs and felled ones, and is ever ready to attack living trees whenever slight wounds in the bark or wood offer an opportunity. It will also attack freshly split stave bolts, and although no present evidence of such attack was encountered, records were obtained at Frankfort, Indiana, of a serious attack which occurred near this place a few years previous. The injury appeared in stave bolts cut from white oak (quercus alba) and approximately twenty-five per cent. or more of this timber over a considerable area was rendered absolutely worthless for this purpose. Actual figures as to the amount of lumber damaged could not be obtained but after close investigations the above estimate is known to be sufficiently low. Injury from this source, is at the present time, apparently slight, since the many saw mills and cut over areas inspected gave but little evidence of its presence.

INJURIES BY THE CARPENTER-WORM.

The presence of this insect is determined by the very large oblong worm holes so common in the heartwood of various oaks, and also in that of the yellow locust. The form is (Prionoxystus robiniae) the larvae of which are large white and pink caterpillars, which hatch from eggs deposited by stout, short-winged, gray moths. The caterpillars are quite large and holes made by them are sometimes one and one-half inches in diameter one way by three-fourths of an inch the other. This form with other large wood-boring grubs or beetles, many times infest the top part of the trunk and large branches of oak trees, and cause what are called "stag-horn" tops. This injury subsequently results in a broken, decayed and otherwise worthless tree. In passing through any timber tract the numerous "stag-horn" tops of the oldest oak trees give strong evidence of the destructive work of these heartwood borers. Loss from this source was found more frequently in southern Indiana, where the number of over-mature trees is most abundant.

METHOD OF CONTROL.—The only method so far suggested for preventing the continued attacks of this insect is to fell and utilize all mature timber that shows any indication of a deceased or otherwise weakened condition of the tops, and to clean up and burn any parts showing evidence of being infested.

THE OAK CARPENTER-WORM.

Injury from this insect was found to be very common, and the loss, if closely estimated, would be large. Of the many lumber and log yards visited by the writer, but few were found where injury from this form was entirely absent. Upon investigation, this infested timber was found to have been felled early in the spring, much of it being cut after active movements of the sap had commenced, and then allowed to remain in the woods until late summer. This procedure insured ideal feeding and breeding places, for not only this special form, but for many others of similar habits. Red oak was most frequently injured, of all the infested forms. The insect was found over a wide area of the State and precautions should be taken to lessen the annual losses caused by its attacks. Much can be done in the way of proper seasonal cutting and more prompt attention to trees after they are once felled.

The attack of this insect does not stop at the lumber yard, and the "tight-stack" in which the newly sawed lumber is often allowed to remain for several days, or even weeks, should be discouraged. The point of attack of this insect being localized largely in the sap wood, thorough and rapid seasoning is the best means of control for sawed lumber. It is also advised to stack the lumber with the sap down. Many of these destructive forms cannot begin work from the under side of a supported plank, as in the "loose stack," and the method where employed has been found effective to a marked degree. This is due to the above stated fact, that these insects work largely in the sapwood, and upon the position of the plank depends largely the ease of attack.

WORM-HOLE INJURIES TO CHESTNUT WOOD.

One of the most common defects in our hardwood trees is found in the worm-holes and pin-holes in chestnut wood. No one having any dealings with this kind of wood can have failed to notice these injuries. The insects causing these worm holes are of such wide distribution that scarcely a chestnut tree of any size can be found

in the hardwood forests, the wood of which does not show more or less injury of this kind.

In this State the injury was confined largely to the old trees which had weakened through age or been injured by other agencies. The chestnut is not so abundant here as farther east and the work of the insect is naturally limited.

The chestnut timber worm (Lymexylon sericeum) is a yellowish-white, slender grub or larva about an inch long. It has a hoodlike enlargement just back of the head, and the opposite end of the body is armed with a horny goughe-like segment, with toothed edges. The adult is a dark-brown, elongate beetle densely covered with fine hairs. In length it varies from four to six-tenths of an inch. The habits of the insect are similar to those of the oak timber worm. It breeds in the wood of dead and down trees and infests wounds in the tissues of living ones. It may also enter healthful trees through knot holes or at the base of dead and broken limbs. Very little is as yet known of the life history of this form, except that the adults emerge about the time the chestnut is in bloom. It is said that the larvae probably live several years in the burrows before being transformed into the adult. This, it seems, would account for the scarcity of the insect in collections. The common occurrence of its work is explained by the fact that holes in the wood of old trees may represent the work of many generations covering as much as two or three centuries.

METHOD OF CONTROL.—The same methods used in combating the oak timber-worms are also applicable to this form. It is also advisable to cut out all old trees and encourage the development of young trees, which are much less liable to attack. These young trees should then be cut for poles or other lumber as soon as they have reached a marketable size.

INJURY TO SECOND-GROWTH HICKORY BY A WOOD-BORING LARVA.

Many examples of a wood-boring insect working on young healthful hickory trees, were found over extended territory. Specimens of the insect could not be obtained and its work is not characteristic enough to insure accurate classification. It places itself naturally, however, in this last class of insects which have been discussed as those not causing the immediate death of the tree. The nature of the injury is shown in Fig. 6. This insect cuts an opening as large as an ordinary lead pencil through the solid bark and wood into the center of the sapling. When the heart is

reached a considerable portion is eaten away, generally in a downward direction. This injury sometimes extends from eighteen to twenty inches from the transverse boring. The direct injury apparently stops at this stage, and the tree, but slightly effected or weakened by the attack soon heals over the opening and to all external appearances is in a perfectly healthful condition. Heart-

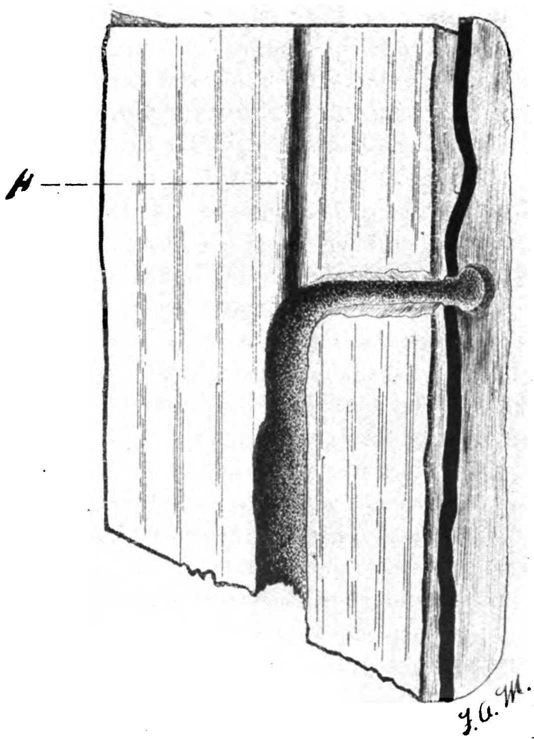


Fig. 6. Work of Borer on Hickory. Injury of this kind is found on young Hickory and, though not resulting in the immediate death of the tree, it causes the very destructive heart-rot so often found in the mature trees. A, heart-rot radiating from injury.

rot immediately begins, however, and continues during the life of the tree. A considerable portion of the tree is thus rendered worthless, and this condition often encountered in mature trees is possibly the result of an early attack by this insect. The life history of the form not being understood no method of prevention can be suggested at this time.

INJURIES TO FELLED TREES, SPOKE TIMBER, POSTS AND TIES; CHARACTER AND EXTENT OF INJURY.

The destructive work of insects which cause serious damage to commercial woods, nuts or even barks consists of burrows and galleries excavated by the young and mature forms of beetles and a few other kinds of insects. Spoke timber in the rough as well as other crude products are injured by pinhole and wormhole defects caused by these forms. Also seasoned rough and dressed lumber and even finished wood material is damaged by the so-called powder post borers, which convert the woody tissue into a mass of fine dust or powder. The annual loss from this source is enormous and far more extensive than is generally recognized. The loss differs from that resulting from insect damage to natural forest resources in that it represents more directly a loss of money invested in material and labor. The nature of the injury by these forms is shown in Fig. 7.

CHARACTER OF INSECT INJURY AS DISTINCTIVE OF SPECIES.

The work of the different kinds of insects as represented by injuries to forest products is the first thing to attract attention. The distinctive character of this work is easily observed, while the insect responsible for it is very seldom noticed. Even if detected it is so extremely difficult to determine by the general observer, from descriptions and illustrations, that the species is rarely recognized. The character of the work, however, is often sufficient in itself to identify the cause and in many cases suggest a remedy.

POWDER POST BORERS.

Various forms of insects under the general class of those injuring felled trees, spoke timber, etc., were encountered over wide areas within the State, and would require a special report, for complete discussion. For this reason only the most important forms will be taken up in this report.

The character work of the powder post beetles is shown in Fig. 7. The injury consists of closely placed burrows, generally packed with the borings in the wood of seasoned products, such as crude and finished handles, cooperage and wagon stock, and inside woodwork in old buildings. Often the wood is completely destroyed or reduced to a powdered condition. This is the work of both the adults and the young stages of some species, or of the larval stages alone of others. In the former, the adults deposit their eggs in

burrows or galleries excavated for the purpose, while in the latter, the eggs are deposited on or beneath the surface of the wood. The grubs complete the destruction by boring through the solid wood in all directions and packing their burrows with the powdered wood. When they are full grown they transform to the adult and emerge from the infested timber through round holes in the sur-

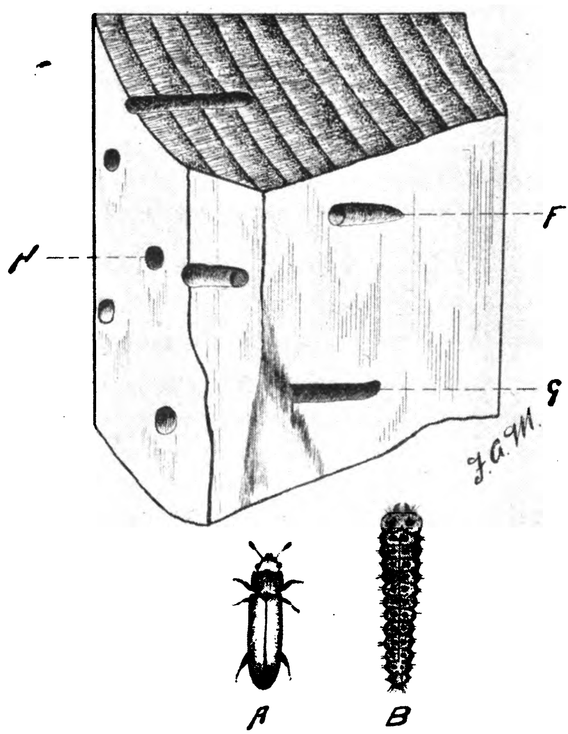


Fig. 7. Work of Powder Post Beetle (Lyctus striatus), in Hickory spoke timber: A, adult; B, larva; F and G, work of larvae; H, exit holes. Drawings from specimens collected at spoke factory, Paoli, Orange County, Indiana.

face. Some species continue to work in the same wood until many generations have developed, or until the wood is entirely destroyed and all available nutritive substance extracted.

This is the most destructive class of insects found in Indiana at the present time. The loss to the spoke manufacturers of southern Indiana is indeed considerable. Figure 7 shows a section cut from a rough hickory spoke and no explanation of the nature of the in-

jury is necessary. This specimen was taken from a pile of rough spokes where large numbers were similarly affected. The investigations were made in July and already emerging broods were noticed. It was found that most of the injured timber had been cut

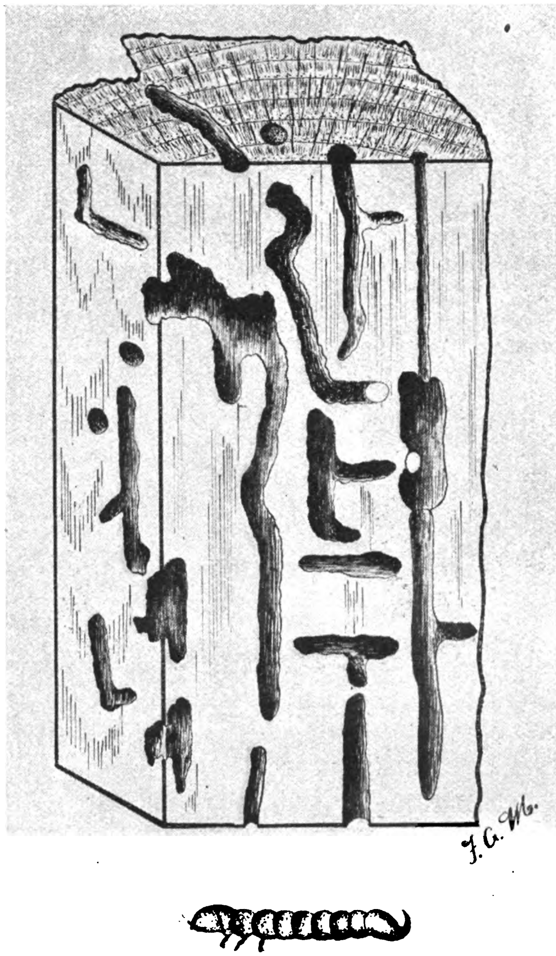


Fig. 8. Work of Timber Worms. Specimens taken from dead tree. The larva shown here is the Sapwood Timber Worm (Hylocoetus lugubris).

early in March or April and left in the woods until late summer. Many bolts were at that time so badly damaged that they were discarded and left in the woods. No effort had been made to burn or destroy them and they only served as additional breeding places

Fig. 9. Young Yellow Poplar so weakened by Timber Worms that it had been easily blown over by the wind.

for continuous generations. Old hickory tops were also examined, and without exception were found badly infested.

Method of Control.—The annual loss from early cuttings in the spring should be conclusive evidence against this method. Soon after being felled the hickory log is in excellent condition for attack from this powder post beetle. If transferred immediately to the mill and worked into the finished product, the chances for loss are lessened, but even then a brood of young insects may be transferred to the mill yard, only to continue its ravages among the seasoning bolts or rough spokes which are generally found there in large numbers. Burning of all infested stumps and limbs and care that no injured parts are allowed to enter the mill yard together with seasonable cutting, should do much to lessen the annual loss.

TIMBER WORMS IN SEASONING PRODUCTS.

Two classes of timber worms are easily and readily recognized. Those attacking living trees and those injuring only dead and felled ones, saw logs, posts and ties. These two classes are made up of numerous forms, which may be separated and distinguished to some degree, by the character of their work.

The nature of the work is shown in Figs. 8, 9, 10 and 11; Fig. 9 being a young poplar which was so weakened by borings that it had been blown over. The figures 10 and 11 were photographed from specimens collected at Knox, Starke County, Indiana. At this place an inspection was made of railroad ties and posts to determine the per cent. of each that was seriously affected by insect attack before being utilized by the railroad company. This inspection was made of surplus stock owned by the Nickle Plate road, and was considered by their section foreman as first grade. The ties and posts were yellow cedar, some of which had been purchased from the south, others from the north.

Out of 2,036 ties inspected, 37 per cent. were seriously affected at one end, as shown in Fig. 11. Out of 1,629 posts, 13 per cent. were badly damaged at the large end, as shown in Fig. 10. The ties cost the railroad company fifty-one cents apiece, and were estimated to last eleven years. Out of this comparatively small number of ties inspected the life of 753 was shortened at least three years. The life of the inspected posts would be shortened much more than that of the ties, since the injured part would come in more direct contact with the soil. These investigations, though not extensive, will furnish some idea of the unnecessary drain

Fig. 10. Section of Yellow Cedar post injured by Timber Worms. Specimen collected from railroad stock at Knox, Indiana.

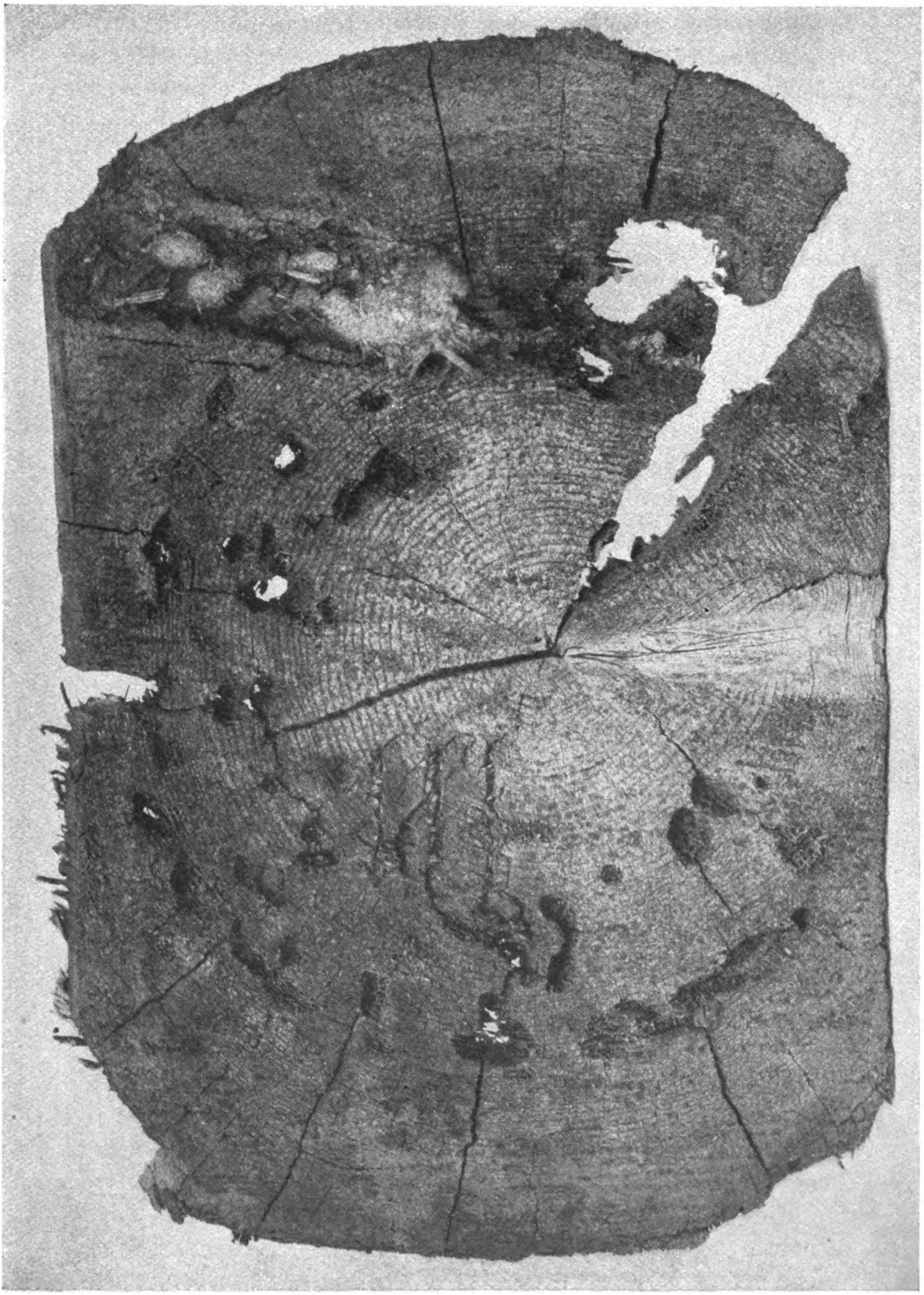


Fig. 11. Section of railroad tie injured by Timber Worms. Specimen from same place as Figure 10.

brought to bear upon the post and tie supplying regions. This condition of railroad stock is common throughout the State and when considered for the United States, the loss would be enormous.

WHITE ANTS OR TERMITES.

The character of injury by white ants or termites, is shown in Fig. 12. It consists of burrows, galleries and tunnels of varying sizes, and of every conceivable shape, extending in all directions

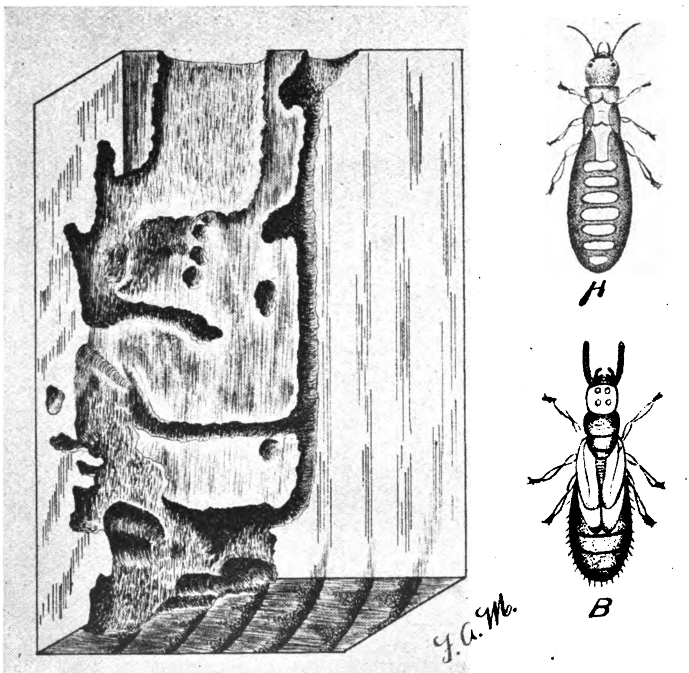


Fig. 12. Work of White Ants, or Termites (Termes flavipes), in sound and dry Red Oak: A, female; B, pupa. Drawings from specimens collected near Paoli, Orange County, Indiana.

through the wood. In wood land almost any log or decayed tree will be found swarming with these dirty yellowish-white insects. They were found working at the base of many trees suffering from fire injury, and the damage thus caused was in many cases worthy of note.

The injury to forest products, both crude and finished, consists of a partial or complete destruction of the infested material. A great variety of products is affected, such as round and square

timber left for some time, next to the ground; posts and poles in the ground; railroad ties, bridge timbers and lumber at the bottom of seasoning stacks. These insects are also destructive to the underpinning, flooring and other wooden parts of buildings which

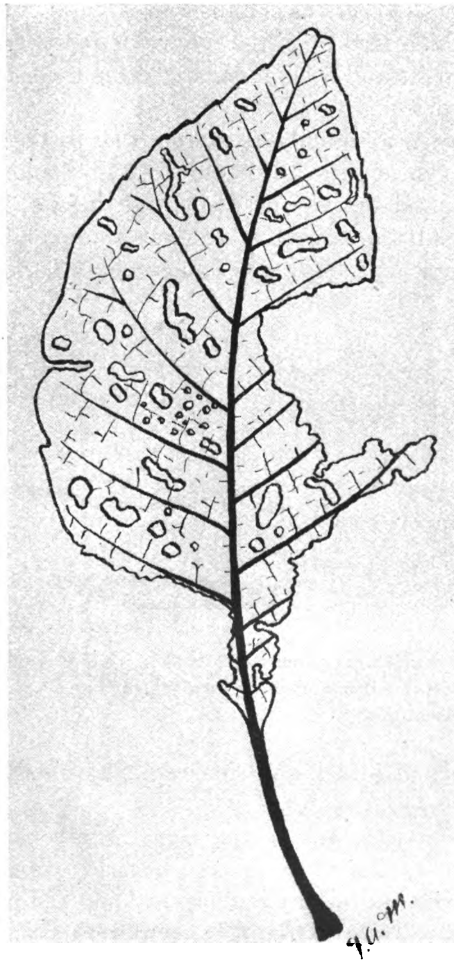


Fig. 13. Leaflet from small Ash sprout, where the damage from leaf-eating insects is most noticeable.

are easily accessible to these destructive forms. The excavations are made for the purpose of obtaining food and to serve as habitations and brooding places for the countless numbers of individuals which occupy them. No means of control other than a removal of all infested parts can be suggested.

INSECT INJURY TO THE FOLIAGE OF TREES.

This injury, though the most common, rarely results in the death of the tree. The most injurious effect of this class of insect is on young seedlings and the rendering unsightly of many shade and ornamental trees. There are numerous species representing several families which feed upon the foliage of forest trees, their number being too great and their economic value too small to justify a detailed discussion.

Hardly a tree is absolutely free from their attack and resulting injuries are shown in Figs. 13, 14, 15, 16, 17, 18 and 19. This type of injury is caused by various leaf-eating insects, and is, indeed, only a very small representation of their manner of attack. Saw-flies, leaf miners, leaf bugs, and numerous others all have their

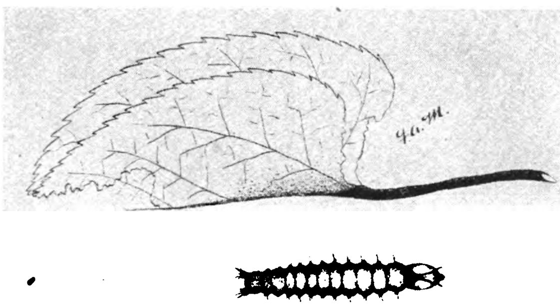


Fig. 14. Leaf Folder on American Linden (Tilia Americana). This, with other leaf eating insects, cause much damage to the Linden in nearly all localities.

peculiar methods of attack and some are very characteristic of the species.

The leaf roolers are among the more numerous types and are found on many species of trees. In no case were they found in alarming numbers and in any one locality and the injury resulting was very slight. Figures 15, 16, 17 and 18 show the methods of attack usually employed by the caterpillars of these insects.

GALL FLIES.

Another class of leaf injury is caused by the gall producing insect. The "gall-flies" belong to the family Cynipidae, and are curious creatures. They are mostly parasites and derive their name from the fact that they produce swellings, protuberances or "galls" of great variety on vegetable tissue. Sometimes they oc-

cur on leaves, twigs, trunks or even on the roots of plants. When these insects are called parasites it is intended to express the idea that they do not actually eat the infested plant tissue. The irritation caused by the larva induces an abnormal growth in the affected part of the plant and within a cell within this growth it has

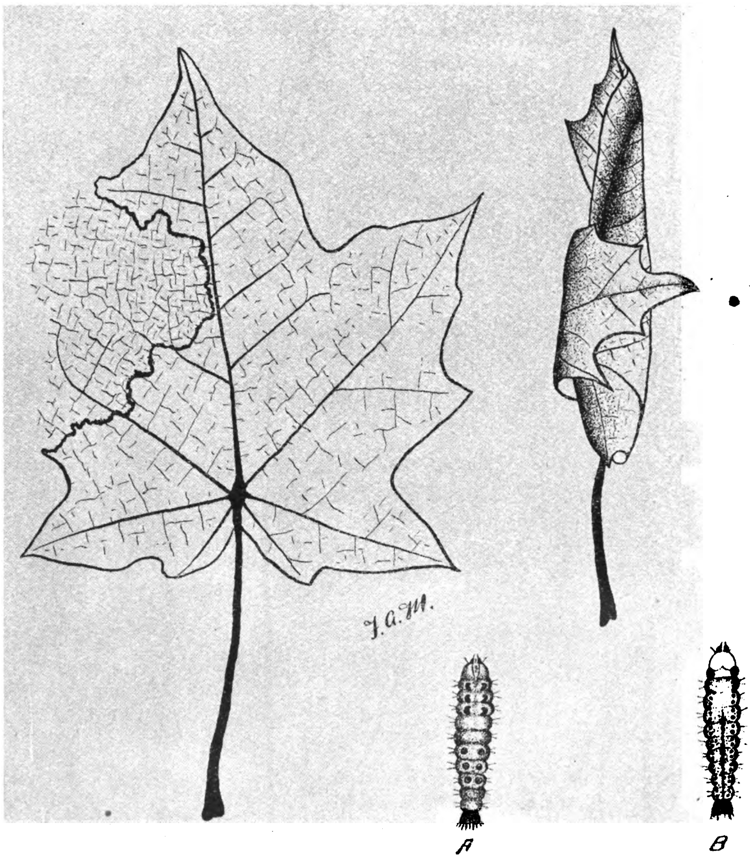


Fig. 15. Sugar Maple attacked by Leaf Roller. Two views of same leaf. During the larval stage of this insect the leaf furnishes the food material. A and B, two views of larva.

its home. The mature insect emerges from this gall, leaving it intact, and disappears without doing further damage to the leaf or other organ upon which it may be growing.

There are only a few injurious species among these gall flies, and the damage to forest trees is very slight. Two forms were noted which had, in a limited number of cases interfered slightly with the

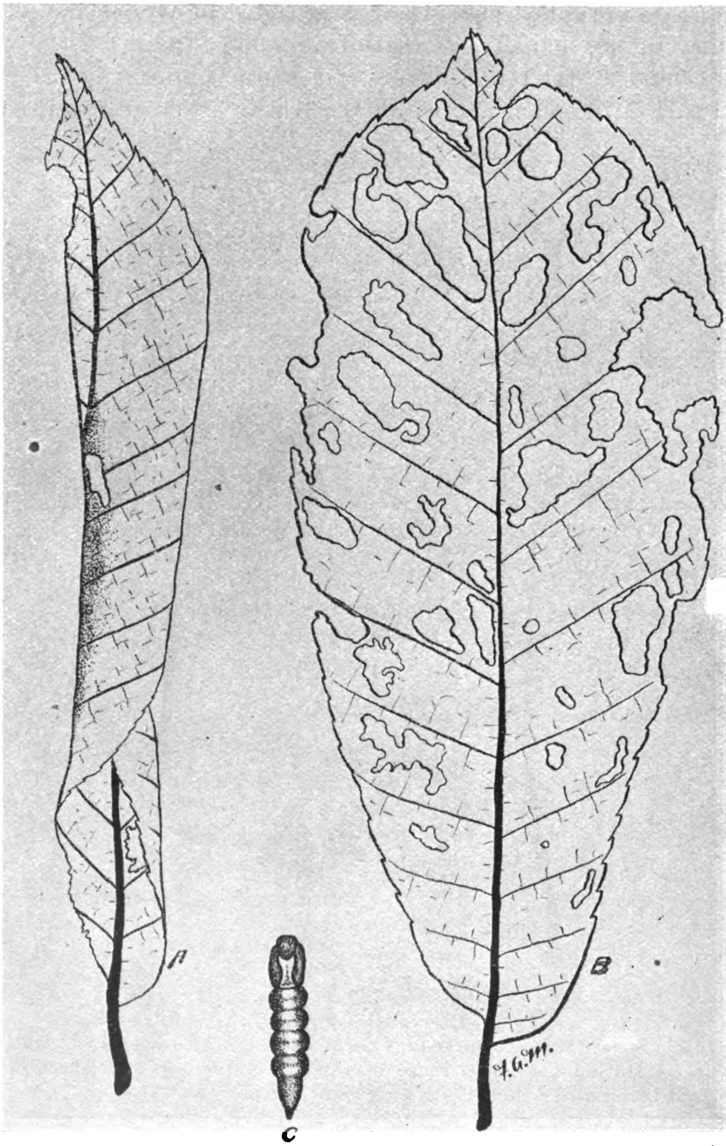


Fig. 16. Leaf Roller on Shellbark Hickory: A, leaf completely folded: B, leaf unfolded. Note the extent to which leaf is eaten. C, pupa of Roller.

growth of the infested trees. One was on the hickory (Hicoria alba), and the other on the elm (Ulmus Americana). This form on the hickory (Phylloxera caryaefallax) causes a cone-shaped gall on the upper surface of the leaf. The insect emerges through an opening in the apex of a much shorter cone on the under side of the leaf. This form was found throughout the State, but more frequently in the southern part.

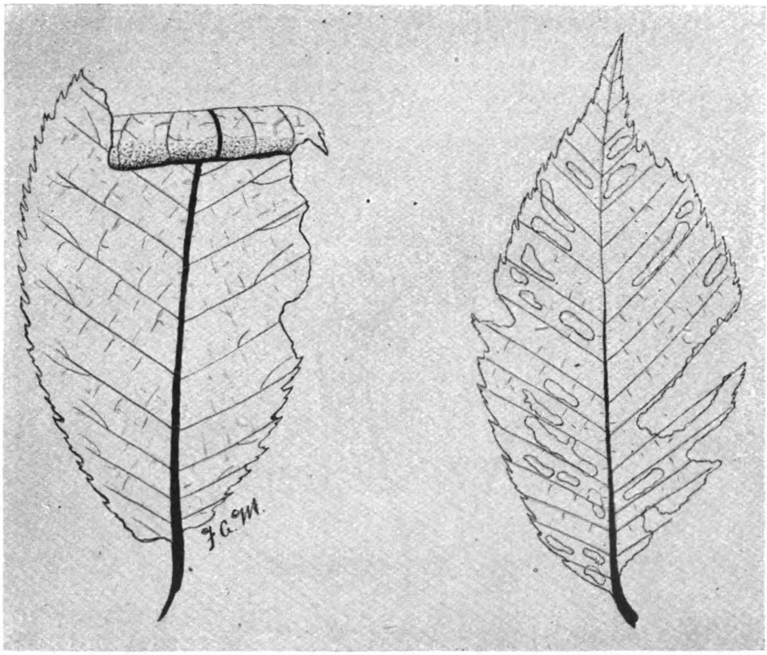


Fig. 17. Effects of defoliating insects on Elm. Injury of this nature is considerable throughout the State.

The other form mentioned is the cock's comb gall on elm (Colopha ulmicola) (Fig. 19). The gall forms on the upper surface of the leaf, with the opening on the lower surface. It resembles the leaf in color, but is frequently tinged with red. It is a very common form, widely distributed over the State. Though so exceedingly common, it is rarely of sufficient abundance to be troublesome. In a few cases it was found on a large percentage of the leaves of small trees, but even then the direct injury to the tree was indeed slight.

COTTONY MAPLE SCALE. (Pulvinaria innumerabilis.)

The past few years have witnessed an increase in the cottony maple scale throughout central Indiana. This occurrence and increase has been noted in several parts of the United States, and in many localities it has been reported in injurious numbers. Places

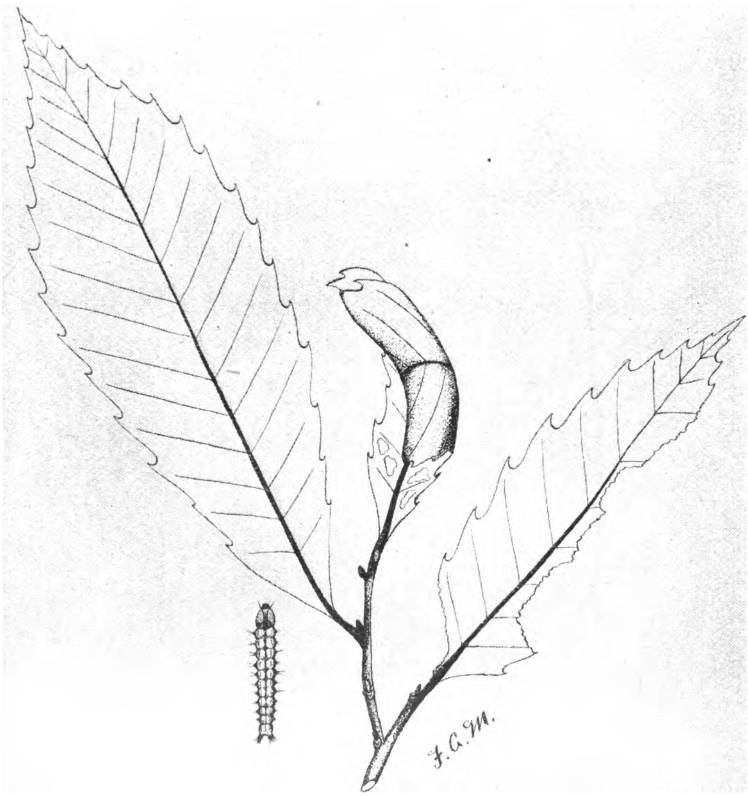


Fig. 18. Chestnut (Castanea dentata). Leaf Roller and effect upon foliage. The Chestnut of Indiana is only very slightly injured by leaf destroying insects.

where the maple tree has been extensively cultivated for shade have experienced serious attacks, and from these places have come the most bitter complaints. The reason for these localized attacks is not positively known, but is supposed to bear some relation to the artificial conditions under which the trees are grown. Under forest conditions the insect appears to be held in check by natural

enemies, which doubtless find protection in the depths of the forest which is denied them among trees planted on private grounds and in parks.

The soft maple (Acer saccharinum) of our own cities has suffered from this insect and some effort should be made to prevent its further spread. Especially have its injurious effects been noted along the streets and in the parks of Indianapolis.

The various species of maple, particularly the soft maple, including the box elder (Acer negundo), are the favorite food plants

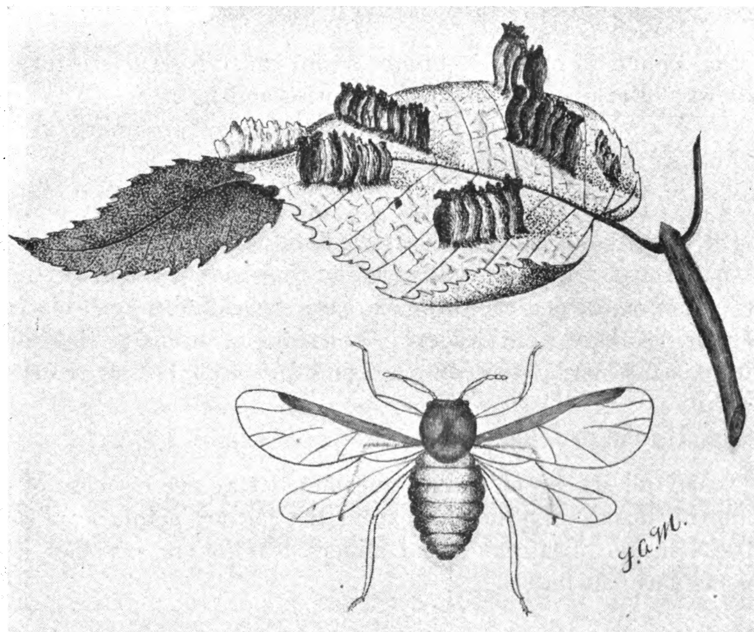


Fig. 19. Cock's-comb Gall (Colopha ulmicola), on leaf of Elm (Ulmus Americana). Also, winged adult of the Gall producing insect. This form may be found over wide areas.

of this insect. It has been found, however, on forty-seven species of trees, shrubs and vines, including maple, oak, linden, elm, willow, poplar, beech, hawthorn, sycamore, locust, hackberry, mulberry, grape, poison-ivy, peach, currant, rose and Virginia creeper. It is possible that a careful study will prove that all of these infestations are not referable to one species.

The form here mentioned (Pulvinaria innumerabilis) has been treated in detail by L. O. Howard, entomologist for the United States Department of Agriculture, in Circular 64, and reference

should be made to this publication for further information. In it the habits and life history of the scale are taken up in full, and practical seasonal treatments for preventing its multiplication and consequent spread are suggested and strongly recommended.

CONCLUSIONS.

The investigations, of which this report is a result, covered sufficient territory to insure a representation of the conditions as existing throughout the State, and from these investigations the following conclusions have been drawn:

(1) Insects causing the death of the tree.

(a) Found in extensive numbers and causing serious injury, as follows: Bark-beetles on oaks, hickories and locust.

(b) Found in limited numbers and causing secondary injury, as follows: Bark-beetles on walnut, wild cherry, hackberry, elm, mulberry and ash; bark-boring grubs on oak and chestnut.

(2) Insects not causing the immediate death of the tree.

(a) Found doing serious damage to timber and timber products, as follows: Carpenter worm on oak; wood-borers on hickory; powder post borers on hickory. On seasoning products, the timber worms, white ants, powder post and pin hole beetles were numerous.

(b) Injury to foliage.

Nearly all species of trees found affected by one or more of the following forms, of which all except the cottony maple scale cause little damage. Leaf eater, leaf miners, leaf rollers, saw flies, scale insects and gall flies.

OAKS, HICKORIES AND ASH AS INFLUENCED BY SOILS AND OTHER ECOLOGICAL FACTORS.

One of the principal objects of this report was to determine, if possible, the influence of physiographical elements and conditions on the growth and natural development of the oaks, hickories and ash. The ecology of the forest being extremely varied and complex, this problem is at once recognized as presenting many confusing and contradictory factors. It would be a vastly more simple undertaking if the forest lands of Indiana were in a primitive state. In almost every case, however, the territory studied was devoid of virgin timber. Consequently, the conclusions arrived at in this report must be accepted in their broadest sense.

The above-named forms, viz., oaks, hickories and ash, being associated groups, the lines of demarcation between local regions of best development are drawn with extreme difficulty. This difficulty increases when the total area studied is in any way limited to specific localities. A great variety in conditions and influences is essential to extreme accuracy. Even then there is a possibility of overlooking or misinterpreting important factors. The localities selected for these investigations are located in parts of the State representing as widely differing conditions as was possible to obtain. Considerable data of a comparative nature has thus been obtained, and the results should be of equal value throughout the State.

Before proceeding further, a short discussion of the geographical distribution of forest trees is deemed necessary. The trees of the United States divide themselves into natural and regular zones or areas, according to climatic conditions. The form and extent of these zones are influenced and modified by local conditions such as: General contour of the land; soils; precipitation and relative humidity. In some cases these climatic zones are separated and distinguished by well marked and absolute boundaries, but more frequently the transitions from one zone to another are gradual and indefinite, one form merging into another in such a complex and confusing manner that the casual observer cannot tell definitely where one form disappears and the other begins. These, or similar conditions are encountered when an attempt is made to separate, into natural groups, the types of trees found within a climatic zone. It should not be understood, however, that a complete separation of these forms has been attempted. The oaks, ash and hickories are many times found growing luxuriantly under ap-

parently similar conditions of soil, soil moisture, aspect of land, etc., and a separation even in the broadest sense would not be practical. The purpose in mind has been more to designate the conditions favorable for their best natural reproduction and development, than to separate them into localized areas.

PHYSICAL CHARACTERISTICS OF THE SOIL.

SOIL INGREDIENTS.

1. Sand.
2. Silt.
3. Clay.
4. Humus.

A mixture of these four ingredients makes a loam which is the most valuable of all soils.

CHARACTER OF INGREDIENTS.

Sand—Grains of quartz large enough to be seen with the naked eye.

Clay—Very fine particles of rocks such as silica, limestone, mica and feldspar.

Silt—Soil particles intermediate between clay and sand. It holds water well and is rich in plant food.

Humus—Mostly decayed vegetation.

LEADING TYPES OF SOILS.

Classed according to the predominating ingredients.

Sandy soils—Contains 80 per cent. of sand and less than 10 per cent. of clay.

Clayey soils—Soils consisting mainly of silt.

Humus soils—Soils in which decayed vegetation predominates.

Loam soils—Combinations of sand, silt, clay and humus, the sand predominating in sandy loams and clay in clayey loams.

PER CENT. OF INGREDIENTS IN VARIOUS SOILS.

Sandy loams—60 to 70 per cent. sand.

Light sandy loam--70 to 80 per cent. sand.

The other ingredients of these soils are clay, silt and humus.

Clay soils—60 per cent. or more of clay and silt. Clay soils being exactly the reverse of sandy soils.

Clay loams—30 to 40 per cent. clay, 25 to 30 per cent. sand.

Heavy clay loam—10 to 25 per cent. sand.

Loess soils—Fine silt or clay, containing 55 to 75 per cent. of

silt and 6 to 15 per cent. of clay. Found over considerable areas in southern Indiana.

In selecting a soil for any purpose special attention must always be given to its physical conditions. S. W. Fletcher says, in his treatise on "Soils, How to Handle and Improve Them," that the cause of the unproductiveness of soils is due to the physical conditions and not to the chemical contents. The problem of soil fertility for any growing form depending, not so much upon the amount of plant food present in the soil, as upon its physical character.

A mechanical analysis of many of the dominant soil types could be given, but would do little to assist the ordinary observer in any undertaking with forest plantings. Also the varying conditions and widely differing types of soils found in Indiana, in addition to the fact that they are most confusingly and miscellaneously distributed over the State, makes it absolutely impossible, and to a degree impracticable, to do more in such a limited time, than consider general and predominating types.

"The soils of Indiana may be roughly classified into three great groups, viz., drift soils, residual soils and alluvial soils. The drift soils are found in the northern three-fourths of the State, are extremely varied in depth and character and are formed of a mass of heterogenous material which was brought to its present resting place by a great glacier or slowly moving sheet of ice, which thousands of years ago covered the area mentioned.

"The residual soils are found in the counties south of the southern limit of the glacier. They were formed, for the most part, in the place where they are now found, by the decay of the underlying limestone or sandstone rocks." (See Fig. 20.) "The variety of materials entering into their composition is therefore limited, and they are, for this reason, among the poorer soils of the State."

"The alluvial soils are those of the river and creek bottoms throughout the State. Gentle rains and earthborn torrents, little trickling rills and strong streams are ever at work tearing down the soils and underlying clays from every slope, and bearing them away to lower levels. The small water-formed trench of today next year becomes a chasm and ages hence a hollow, and the transported material is gradually deposited as alluvial soil over the so-called 'bottom-land' which are annually overflowed.

"The drift soils cover the northern and central portion of Indiana. derived, as they were, from various primary and igneous rocks in the far north, ground fine and thoroughly mixed as they were

Fig. 20. Outcropping of limestone rock near Paoli, Indiana. The relation of the underlying rock strata to soil formation is plainly evident in the above photograph.

by the onward moving force of a mighty glacier, are usually rich in all the necessary constituents of plant food. Neither they nor the alluvial soils require a large annual outlay for fertilizers, as do the residual soils of southern Indiana, over which the drift of the glacial period did not extend."—Blatchley, 21st Annual Report of the Department of Geology and Natural Resources, 1896, pages 21 and 22, State of Indiana.

The soils of the northern and central counties assigned for investigation came under the class of drift soils, while those of the southern came under residual soils. The alluvial soils being distributed to some extent over the entire State, are found in each of the three groups of counties. These counties being assigned in groups of threes, each group representing consecutively northern, central and southern conditions, the soils and other topographical features will only be discussed for the groups, and not for each separate county.

The northern group therefore, consisting of Marshall, Starke and Kosciusko, lies in the northern central part of the State. Data collected by the United States bureau of soils shows a fairly uniform distribution of rainfall throughout the year, with a maximum during the growing season. The temperature is characterized by sudden changes and by alternating freezes and thaws, during the winter and early spring. From a tree planting standpoint these are unfavorable conditions and many reports were received where young growths of catalpa and black walnut were killed or "frozen back" to such a degree that the season's growth was indeed slight. See Fig. 30, which is a planting of black walnut where numerous trees were killed by severe and rapid changes in the temperature, and by the cold winds which sweep across this part of the State during the winter months. Soil conditions also played a most important part in the success of this planting, but will be discussed later. Specific examples cannot be considered at this point, but must give place to a more general description of soil and surface conditions.

This northern group of counties, falling as it did directly in the path of the glacier, is covered to a great depth by drift deposits. No outcrop of stratified rock is seen, nor has it been reached by the deepest borings. The character of the surface materials though not widely differing, is found to vary to a considerable extent with the general topography of the land.

Generally speaking, a line running north and south through the center of Marshall County separates the sandy soils from the clay

soils. What are known as "clay soils," to which the government has given the name, Marshall loam, is found principally east of this line. The "sandy soils" occur west of this central line and are of several distinct types. Three of the principal ones are, Marshall sandy loam, Miami sand and Marshall sand.

The topography of this group of counties is quite level, with small areas of rolling country along Yellow River and in the vicinity immediately surrounding the lakes. That part lying east of the central line above mentioned is comparatively level or gently rolling, with scattered groups of low hills. Westward from this line the land takes on a more rolling topography, until well into Starke County, where with many intervening depressions or slight valleys it gradually assumes a low level aspect, characteristic of the Kankakee region. The so-called bowlder clay is in this part found at greater depths, while the sand increases until finally the "sand barrens" are reached. These barrens seem to be wind-blown deposits and frequently take on the characteristics of sand dunes. They are also found in many places to have the appearance of old beach lines. There are many basins and depressions over the entire area, but are more extensive east of the central line. The basins are generally known as marsh, and the soil found within them is ordinarily classified as muck. In many parts bowlders are scattered over the surface of the ground and consist chiefly of granite, gneiss and other metamorphic rocks. From records obtained from borings these rocks seem to be more abundant near the surface. This is a natural result and accounts only to a very slight degree for the different classes of soils found in this region.

As many as nine types of soils have been classified and described from this region. They range in texture from sand to clay loam and are thus seen to offer a wide diversity as to productivity. Of these nine types, the Marshall loam occupies by far the largest and most uniform areas. It is found chiefly east of the dividing line, but occurs west of it in small areas. This type of soil was originally covered with a heavy growth of black walnut, and is still locally known as the "black walnut land." Even now an occasional small patch is seen where the original timber has been reserved, but these patches are rapidly disappearing and in a few years will be entirely removed.

The sandy soils, found west of the central dividing line, are comparatively shallow and of medium texture. In the depressions and low valleys the soil becomes more loamy, darker and extends to greater depths. These sand soils, of which there are three prin-

cipal types, are generally rolling and many times resemble sand dunes in form and appearance. It is highly probable that a large portion of this section of the country was formerly old sand dunes on which plants have obtained a foothold and checked the action of the wind and the resulting movements of the sand. Considerable of this type was originally covered with timber, but the trees were chiefly scrub oaks with a few other less valuable trees of medium size scattered here and there.

The second group of counties, Clinton, Howard and Grant, is centrally located and must be taken as typical of central Indiana. The climatic conditions are about the same as the average mean temperature and precipitation for the State. The surface features of this area consist of undulating plains, with broad level areas between the natural drainage basins, which become more or less rolling and sometimes quite hilly as they near the water courses.

The underlying rocks are in some places exposed along the streams that have cut through the glacial drift. In general, however, they have such a limited exposure as to have little influence upon the character and productiveness of the soils. The greater part of the area is covered with a comparatively deep deposit of glacial drift, broken and eroded in many places by natural waterways. Hills of washed gravel are also frequently found which were deposited by streams beneath the melting glacier, the finer sediments being carried on to form the surface soils of areas farther south.

The soils of this locality are largely made up of clay loam, with small intervening areas of muck and sandy loam. Four prevailing types are recognized. The clay loam is the type most frequently found and ranges in depth from 6 to 12 inches. It grades into a clay or heavy clay loam of a stiff heavy character, which is generally underlain by gravel or gravelly clay. At varying depths in the subsoil are found beds of gravel and sand, which when near the surface have resulted in a gravelly loam, underlain by gravelly clay or gravel. These gravelly clays are frequently met with throughout the extent of central Indiana. They are, however, in narrow streaks, particularly along river courses, and are in general the result of surface washing and erosion.

Under the above conditions the original growth of timber was magnificent. It consisted of a mixture of oaks, ash, hickories, elm, beech and sugar maple. This original stand, once dense and heavy, has gradually disappeared, and now instead of extensive forests we find a few scattered woodlots.

Fig. 21. Washed and eroded condition of a low hill from which all timber and underbrush had been removed. Photograph taken near Paoli, Orange County, Indiana.

The other important soil types of these counties are black clay loam, Madison loam, consisting of brown or yellow loam or fine sandy loam from 8 to 14 inches deep, and muck, a term given to the class of soils in which organic matter in various degrees of decomposition is the dominant characteristics.

The third group of counties, Orange, Martin and Washington, are of the southern location and are indeed typical of this rough, broken region. Being one of the most heavily timbered sections of the State, the settlers from the earliest down to the present time, have depended largely, and in many cases wholly, upon forest products as their main source of income. That this statement holds true to a certain extent, even to the present time, is due, almost entirely, to the physiographic features of this section of the State.

Two controlling factors have been active in the physiographic development of this locality—the limestone, sandstone and arenacious shale, and the black slaty shale. The upper strata of the first group, which cap the hills in the southern part of these counties, have resisted the agencies of erosion better than the softer underlying shale,.and the results are a broken and hilly topography. The shales belonging to the second group, which underlie the soils in many localities, have given rise to a more rolling and undulating character. The numerous hills have been cut by streams which have formed v-shaped valleys. Excellent examples of such valleys are common in the western part of the section along the course of the east fork of White River, which has cut its way many feet through the sandstone deposits. Broad valleys and level uplands are often encountered, where the summits of the surrounding hills are comparatively level, and the hillsides slope gradually towards the small streams. More often, however, the hillsides are steep and the soil covering very thin. At these points erosion and weathering are most effective and the removal of the timber and underbrush soon cause them to assume a desolate appearance. Many such washed and denuded areas are present throughout our southern counties and are generally the direct result of a poor understanding of natural laws and existing conditions. For an example of such conditions, see Fig. 21. This photograph represents the general washed and weathered condition of much of the hilly land surrounding Paoli, Orange County. Also, see Fig. 22, where the steep hillside is securely held against erosive agencies by a dense and luxuriant growth of red cedar.

The geological formations which underlie this area are most frequently exposed on the steeper slopes and are indeed seldom at any

Fig. 22. Young growth of Red Cedar on hillside, showing nature's method of soil binding against the agencies of erosion.

great depth below the surface. See Fig. 20. Many of these underlying rocks are of a type that weather rapidly upon exposure, and have undoubtedly entered largely into the composition of the various classes of soils. See Fig. 20 for outcropping of rock strata, where all gradations from the solid rocks to the heavy clay soil is plainly evident. Being derived in this way, from the underlying rocks, the soils of this region consequently present a more limited variety of conditions, favorable to the development of plant life. Although it is believed by many that a considerable portion of the surface material covering many of these southern counties is of glacial origin, it is very probable that it was mainly local in its derivation. This probability is confirmed by the scarcity of glacial bowlders or fragments of igneous rocks in the soil.

Four types of soils are found in this locality, all coming under the general head of silt soils. Of these, three are thought to be derived directly from the weathering of the underlying geological formations. The fourth, which occurs only in the low, flat "river bottom land," is derived from materials brought down and deposited by streams.

This general discussion of soil formation and distribution has been thought necessary to the better understanding of the following statements, which relate to the conditions most favorable to the growth of the oaks, ashes and hickories.

OAKS.

The oaks are widely distributed over the central and eastern parts of the United States. The natural range, generally speaking, extends from Nova Scotia to the region west of Lake Superior and south to eastern Kansas and northern Georgia. This wide range of distribution suggests the varying conditions under which many species of the oaks may be found. They are associated forms and are found growing with elm, basswood, chestnut, hickories and other of the common hardwoods. Their soil requirements are variable and in the nine localities investigated they were found growing equally well upon several distinct types of soils. Only when we reach the low undrained glacial basins of northern Indiana do we see a falling off in the development of the oaks. In this region we have the magnificent forms of central and southern Indiana replaced by the stunted Spanish and swamp white oaks. These forms are too near their northern limit to develop naturally, and the other valuable species extending this far north are so influenced by physiographic conditions that they rarely exceed more than a low branching form unfit for commercial purposes.

RED OAK. (Quercus rubra.)

The red oak has been found over such a wide range of soil conditions that the statement has been made that it will thrive in any soil except an undrained one. This statement includes abandoned and otherwise worn out soils. It has been found more practical, however, to limit this exceedingly general statement and say that red oak is best suited to porous, sandy or gravelly clay soils. It thus stands intermediate in its requirements between the white oak and several of the black oaks. It always requires good drainage, and no planting should be attempted on any soil, however fertile, unless this physiographic feature is present.

WHITE OAK. (Quercus alba.)

The white oak is found in the north-central, central and eastern States. Indiana falls directly within its region of best development. This region, which is of more far-reaching boundaries than the State of Indiana, includes the western slope of the Allegheny Mountains and other portions of the valley of the Ohio River. The white oak is the most valuable of American oaks, and is indeed worthy of closer attention than it is receiving at the present time. In certain isolated areas and on a few abandoned hillsides in southern Indiana, the white oak is making a slow but otherwise persistent effort at natural reproduction. This effort, however, receives no artificial aid and is, in a majority of cases, even interfered with by an utter disregard of natural laws. This interference with natural reproduction is a result of careless lumbering and a failure on the part of the land owners to acquaint themselves with the principles of the forest policy which is now being agitated through every State of our Union. This is another phase of the subject under discussion, however, and cannot be considered here.

The white oak is found to do best on rather deep and moderately moist well-drained soils. A loamy sand where the amount of sand may run as high as 80 per cent., and situated in warm localities, is found to be exceedingly favorable. It will also succeed on poorer soils and is often found where the per cent. of clay is quite large. It is recognized as a light needing species and though capable of enduring shade while very young, never does so with advantage.

BUR OAK. (Quercus macrocarpa.)

The bur oak being closely associated with the white oak, is found over a wide range. It is distributed from Manitoba to Texas, and eastward to the Atlantic coast. It is an important tree in our

State and has reached its greatest development throughout the Mississippi basin. Here it is found associated with white oak, basswood, white ash, cottonwood, black walnut and some of the hickories. About the Great Lakes and in the Dakotas it is sometimes found in pure stands, forming the characteristic "oak opening." Throughout this section of its natural range, however, it never occurs except in the presence of other forms.

The bur oak requires a better soil than the white oak, being best suited to a deep, rich, so-called "river-bottom" soil. A rich loam is indeed its favorable soil, but it is often found growing and maintaining itself in poorer upland localities. It is recommended for planting only where the soils are fairly rich, and though low, they should be well drained. This species, though somewhat intolerant, will endure more shading than white oak. It is not thought, however, that it is intolerant to such an extent that it could be recommended as an undergrowth beneath some more rapidly growing form.

Two other species of oaks about which only a few words can be said, are the chinquapin oak (quercus acuminata) and the swamp white oak (quercus platanoides). The chinquapin oak is another form which reaches its best development in the lower Ohio Valley. Like most other oaks it will thrive on a wide range of soils. It does best on deep, rich, moist, well-drained river bottom land. It is also not uncommonly found on dry limestone situations such as are found in southern Indiana.

The swamp oak which reaches its greatest size south of the Great Lakes, is found on a deep moist soil or even in inundated swamps. Low banks of water courses are often grown up with this form and many loose, rich and fairly moist uplands are often covered by a mixed growth of which this species forms an important factor.

ASHES.

The ashes are distributed over a considerable portion of the United States east of the Rocky Mountains, the green ash even extending into those mountains in Utah and New Mexico. They are most abundant in the Mississippi Valley, where, though often occurring as the leading species, they seldom occur in large masses or pure stands. More generally they are found as individuals or in small groups among other hardwoods. The species with which they are associated are maples, elms, basswood, birches, walnuts and oaks.

WHITE ASH. (Fraxinus Americana.)

The white ash is a natural forest form, reaching its maximum size in the lower Ohio Valley. In the forest it is a tall, slender tree surmounted by a crown, somewhat open and made up of stout upright branches. Its natural distribution is from Nova Scotia and Newfoundland to northern Florida, central Alabama and Mississippi and westward to Ontario, northern Minnesota, eastern Nebraska, Kansas, Indian Territory and Texas. Its range for economic planting has been designated by the Government Forest Service as extending from the valley of the Wabash and Ohio Rivers, north and west through Indiana and Illinois to the region of the Great Lakes; westward through Iowa, southern Minnesota and eastern South Dakota; southward through eastern Nebraska and Kansas into northern Oklahoma and Indian Territory.

In its habits and growth the white ash prefers a rich moist soil. The finest trees have been found in the bottom lands of rivers and in the valleys of rolling uplands. The mild climate of the west central portion of its range offers the most favorable condition for its development. While apparently doing best in a protected valley, on a loam soil containing sufficient sand to make it light and easily worked, the white ash will thrive, under much less favorable conditions, and even in adverse localities. Indeed a wet, compact soil is not objectionable if well drained. It has been said that a porous sub-soil is absolutely essential and that a water table at a depth of from 10 to 12 feet offers considerable advantages. This last statement was varied by observations in the southern counties, where the valleys and low hillsides were, in many cases, found supporting a vigorous growth of young ash seedlings. The ash seedlings will endure considerable shading while young, but it requires light for its perfect development.

GREEN ASH. (Fraxinus lanceolata.)

The green ash, a species closely related to the white ash is, when forest grown, a medium sized, rather round-topped tree with a straight, slender bole and branches more spreading than in the case of the white ash. It rarely exceeds a height of 60 feet and a diameter of 24 inches. It is thus a much smaller tree than the white ash, which reaches a height of 80 feet and a diameter of 3 feet.

In distribution it follows closely the boundaries of the white ash, extending them, however, in the north and southwest part of its range. Along the drainage basins of the middle west this form has sometimes been found as the dominant species, but more often

it occurs as scattered individuals. It is most common and best developed in the Mississippi valley, and decreases in number and importance as we follow it eastward, until it becomes rather infrequent.

The green ash will succeed best if planted in low, moist localities. This does not mean that it requires a rich soil, for it has been found making fair growth on dry sandy loam or even on a stiff clay. It is indeed one of the forms which can exist and even develop, under conditions of temperature and moisture which would be fatal to many other forms. It has been grown with some degree of success on upland clay, and although its growth in such situations is much slower than in deep river bottom soils, it is thought that it could be handled with greater safety than most other trees. Indeed, where unfavorable conditions are encountered and a question of hardiness of species arises, the white ash should always yield preference to the smaller green ash. Even on the arid plains of western Kansas and Nebraska, this species has survived on abandoned claims where nearly all others have failed. For economic planting its range has not extended beyond its natural distribution, but it is probable that on account of its resistance to adverse conditions it may prove extremely valuable for planting in regions now being developed throughout the west, which extend even beyond its natural boundaries.

HICKORIES.

The hickories which form the last group to be considered here, are found widely distributed from southern Maine, west through southern Michigan to eastern Kansas, Nebraska and Texas, and south along the Appalachian Mountains to northern Florida, Alabama and Mississippi. The region of best development is on the western slopes of the Appalachian and along the Ohio River and its tributaries.

SHAGBARK HICKORY. (Hicoria ovata.)

The shagbark hickory, when forest-grown, usually attains a height of 70 to 80 feet and a diameter of 2 feet. When grown free, as is usually the case when it is planted for nuts, it branches near the base, and the crown becomes full. Under forest conditions, however, the trunk is straight and clear, and the crown small and open.

The shagbark is generally found growing with other deciduous trees, although it is not uncommon to find comparatively pure

stands. Its associate forms are principally the oaks, chestnut, ashes, maples and yellow poplar.

Since it is closely associated with these forms it would naturally be expected to demand about the same requirements of soil and climate. This is true, however, only to a certain degree, and though it may be found growing rapidly under the same soil conditions as these other associated forms, it must not be supposed that it possesses no individual characteristics. The following peculiarities have been observed and are thought necessary to the best development of the shagbark hickory.

A deep, rich, loamy soil is preferred, but many fine trees are found on other moderately rich soils. Even some of the poorer soils, as those derived directly from sandstone and limestone, which are not so compact as to prevent the toproot from penetrating to a moist subsoil, may produce a good growth of hickory. Such conditions are present in the southern part of Orange County, where the sandstone soils are in many instances covered with an almost pure stand of hickory. Hard, compact clay soils or soils containing a large per cent. of sand, underlain by a layer of impervious clay or hardpan, are never recommended for hickory plantings. In many localities in our central counties the absence of hickory may be traced to a subsoil of compact retentive clay, or an almost impenetrable layer of hardpan.

The strong toproot which the shagbark hickory develops must be allowed to penetrate readily to a moist but not a wet subsoil. To make a more general statement it may be said that this tree will make good growth throughout the Middle States in well-drained situations where the subsoil is loose and moist, and wherever it can get abundant sunlight.

The shagbark is intolerant of shade and develops normally, only, when growing in pure stand or when surrounded by other trees which only slightly obstruct the light. When shaded it grows slowly, and very early assumes a dwarfed appearance. Under proper conditions, however, its rate of growth is fairly rapid, and compares exceedingly well with that of the white oak.

Some of the smaller hickories, such as the pignut or swamp hickory (Hicoria minima), and the mockernut (Hicoria alba), are widely distributed over the eastern United States. They are most abundant in the southern States, this being especially true of the mockernut or Hicoria alba.

The first named species often attains a height of 80 feet and a diameter of 2 feet. It is found growing under less favorable con-

ditions than the shagbark. It prefers low, moist situations and will even succeed on wet, swamp grounds. On the other hand, the mockernut, which may reach a height of 90 feet and a diameter of 3 feet, does equally well on poorer and especially on drier soils which may contain considerable clay or gravel. It is said that it will succeed even on rocky barrens. It is a tree, the wood of which is similar to that of the shagbark. It is used to much the same purpose, and were it not for the ravages of insects upon it, it would be a valuable form with which to replace the shagbark on the poorer, drier soils of southern Indiana.

TREE PLANTING.

In connection with the work outlined in the introduction of this report, private tree plantings throughout the assigned territory were investigated. The purpose of these investigations being to determine to what extent such plantings were being undertaken, together with a study of the methods employed in planting and cultivating, and the degree of success attained under the various conditions.

As to the extent of these plantings, little can be said. A thorough investigation of the entire State would be necessary before comparative and accurate figures could be given. It can be said, however, that the relative number of such plantings is extremely small. They are found to be most numerous in northern and central Indiana, and are almost absent in the southern counties. This state of affairs is supposed to be a natural result of the general timber conditions of the State.

The constantly decreasing supply of post timber, is one phase of this general forest condition of the State. With the demand for such timber increasing and the source of supply rapidly decreasing, not only in Indiana, but over the entire central west, the farmer is being aroused to a state of activity which will eventually result in an investigation of the possibilities of growing his own posts. Indeed, many have already taken up this proposition and it is with the idea of encouraging such undertakings that the following data and photographs have been collected:

Fig. 23. Catalpa Planting. In this planting both species, Catalpa bignonoides and Catalpa speciosa, have been used. The mixture is a result of poor selection of seed and an inability to determine the valuable species (catalpa speciosa) when in the seedling stage. Many of the trees have branches low and their value will consequently remain below the maximum.

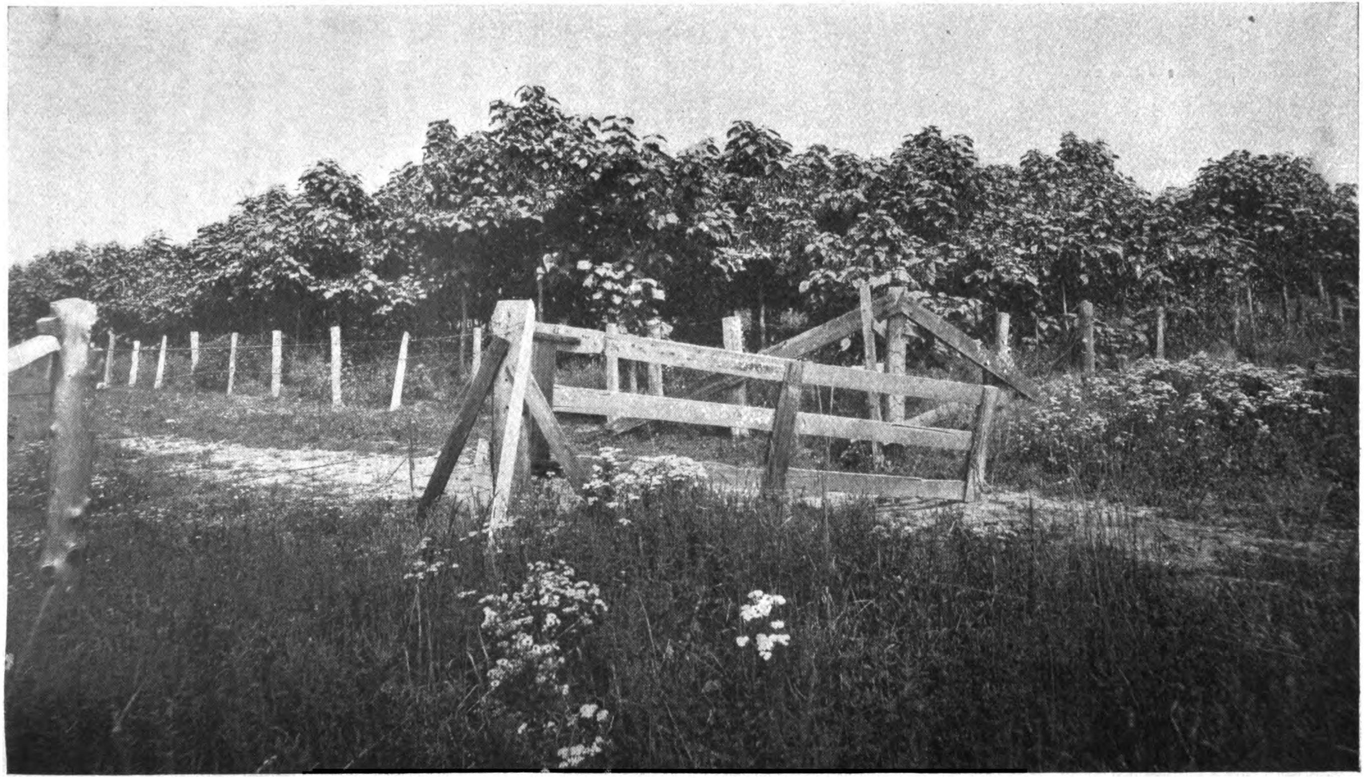


Fig. 23. Catalpa planting on farm of Rockhill Bros., Ft. Wayne, Indiana.

The planting was made by the Rockhill brothers near Fort Wayne, Indiana. The trees were planted five years ago and were cut back at the end of the second year. The rows were eight feet apart and the trees four to five feet apart in the rows. At the time the investigation was made, many of the trees would have furnished two good posts. The planting had been cultivated by the ordinary methods of cultivation, for four successive years. The dense crowded condition of the trees shown in the photograph would suggest the removal of every other tree in each row.

Figure 24. Catalpa planting on farm of A. K. Kennert, six miles north of Fort Wayne. These trees are three years old and have an average height of ten feet. The planting had not been cut back, but each individual tree had been annually pruned. This accounts for the clear trunks and light crowns. This planting contains only the species (Catalpa speciosa) of which the clear straight trunk and absence of numerous side branches are characteristic. The photograph gives an idea of the wide spacing of the trees which is seven feet each way.

The best spacing for catalpa is not at present known. Much is known to depend, however, upon the purpose for which the trees are intended and upon the soil conditions. The trees may be set quite near together, if thinned at the proper time, but it is safest, never to plant so many trees on the ground that when thinning is to be done, the trees which are taken out must be thrown away on account of inferior size. If one would grow catalpa successfully he must reduce the struggle for existence to the lowest possible limit. It is said that side branches can be more economically removed by pruning than by close planting. And that an upright growth can be secured at less cost than by overcrowding of trees. Cutting the young trees off close to the ground at the end of the second or third years' growth, insures straight trunks and reduces considerably the amount of pruning, since but few side branches ever develop on sprouts which spring from stumps of trees that are cut back.

Figure 25. Planting of black locust (Robinia pseudacacia). The trees are three years old and the planting was made in the edge of a woods in heavy unprepared sod. They were planted in a miscellaneous and careless manner and had received no cultivation. The result is plainly shown in the photograph, where it is seen that many of the two year old seedlings are no taller than the blue-grass in which they are growing.

At least fifty per cent. of this planting was already attacked by the destructive locust borer. The drawings in Fig. 4 were made

Fig. 24. Catalpa planting three years old, on farm of A. K. Kennert, six miles north of Ft. Wayne, Indiana.

from specimens collected from this planting, and show the general nature of the injury to young trees.

Figure 26. Black walnut planting near Frankfort, Indiana. The trees are fifteen years old and had reached a diameter growth of from two to six inches They were planted in rows fourteen feet apart and the trees were from six inches to two feet apart in the rows. The planting was growing vigorously but was in great need of thinning. Many small trees were being suppressed and stunted in growth by the dense shading and general crowded condition. The soil was a deep black loam, suitable in every way for such a planting.

Figure 27. The cottonwood growth represented in this photograph was serving effectively as a wind break to the farm buildings of James Mackentire. The planting was located about 100 yards to the northwest of the group of buildings and its effectiveness has been appreciable for several years. The trees are now thirteen years old, being planted to their permanent location from one year old cuttings. They are in rows 18 feet apart and range from 10 to 12 feet apart in rows. They were from 6 to 12 inches in diameter and had been allowed to branch low, thus forming dense heavy crowns, which would make them more effective against the wind. This is an example of where one of our most common trees, of somewhat low commercial value, has been utilized for a definite and valuable purpose on account of its rapid and persistent growing.

Figures 28, 29 and 30 show various conditions of a black walnut planting on the farm of J. C. Birdsell, two miles east of South Bend, Ind. This planting of one hundred thousand trees was made about twenty years ago. It was reported upon by Mr. Stanley Coulter in his catalogue of the "Flowering Plants of Indiana," published in 1899. At that time, when the trees were only a few years old, they were said to be of good size and of thrifty appearance. The soil being thin, containing considerable sand and underlain directly by sand and gravel, was noted as being apparently favorable to the development of black walnut.

The trees being only a few years old when the above mentioned report was made, had not made sufficient growth to show the marked effect of the unfavorable conditions of soil and climate. Figures 29 and 30, which are photographs of this same planting, give conclusive evidence of the conditions under which these trees have been struggling. Figure 30 shows one of the isolated groves so characteristic of this planting. These scattered groves have de-

Fig. 25. Planting of Black Locust in edge of woods, on farm of J. H. Gerding, six miles west of Ft. Wayne, Indiana. Young Locust trees in foreground of picture.

veloped fairly well as a result of slight depressions in the land, where the soil is deeper, contains less sand and more moisture. Figure 28 represents the conditions along one side of the planting where the soil is richer and the ground lowest. Figure 30 was taken from the highest point in the planting and gives a more general idea of the unevenness of the growth as a whole. Note the low dwarfed forms in the foreground and the gradual increase in size and thriftiness as the lower, less sandy ground is approached. Figures 28, 29 and 30 may be compared with Figure 26, which is a planting of black walnut with soil and climatic conditions entirely different. The difference in results of a fifteen-year growth in a deep, rich sandy loam and a twenty-year growth in a thin sandy soil, in a locality exposed to the cold north and northwest winds, is well brought out by comparing these two plantings.

"The ideal conditions for growth of the black walnut are found in the rich, moist soil of bottom lands or on fertile hillsides which are protected from cold, sweeping winds. A calcareous soil or a sandy loam, containing a large quantity of humus, overlying a deep subsoil of gravel, and a water table in which the long taproots can find a continual supply of moisture, furnishes the best conditions for growth. The surface soil should be moist, but not wet, and the subsoil porous.

"While not especially adapted to widely varying conditions, the black walnut will grow in many localities outside of its natural range; but its form and rate of growth are appreciably affected by its environment. Throughout the entire Middle West, south of the forty-fifth parallel, planting on limited areas may be attempted with fair prospects of success on all fertile prairie lands, and especially in coves, valleys and extensive bottom lands where the requisite moisture is present and partial protection from the wind can be had. This latter requirement may be secured by starting the plantation in the lee of a natural wind-break or by planting a shelter belt of hardy rapid-growing species on the exposed sides." —United States Department of Agriculture, Forest Service Circular 88, page 2.

Fig. 26. Fifteen year old Black Walnut planting, on farm of Anna Congleton, three miles southwest of Frankfort, Indiana.

Fig. 27. Wind break or shelter belt of Cottonwood (Populus deltoides), on farm of James Mackentire, two miles southeast of Frankfort, Indiana.

Fig. 28. Black Walnut planting, on farm of J. C. Birdsell, two miles east of South Bend, Indiana.

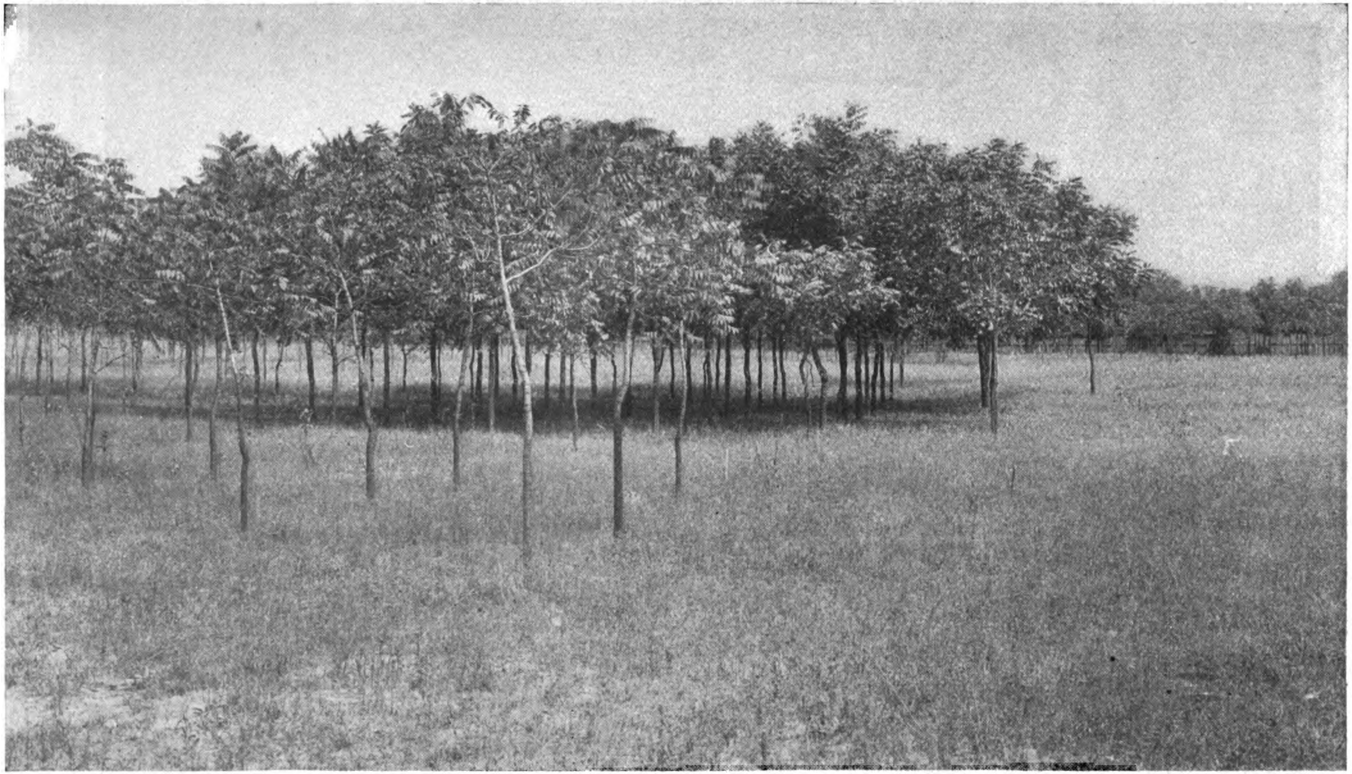
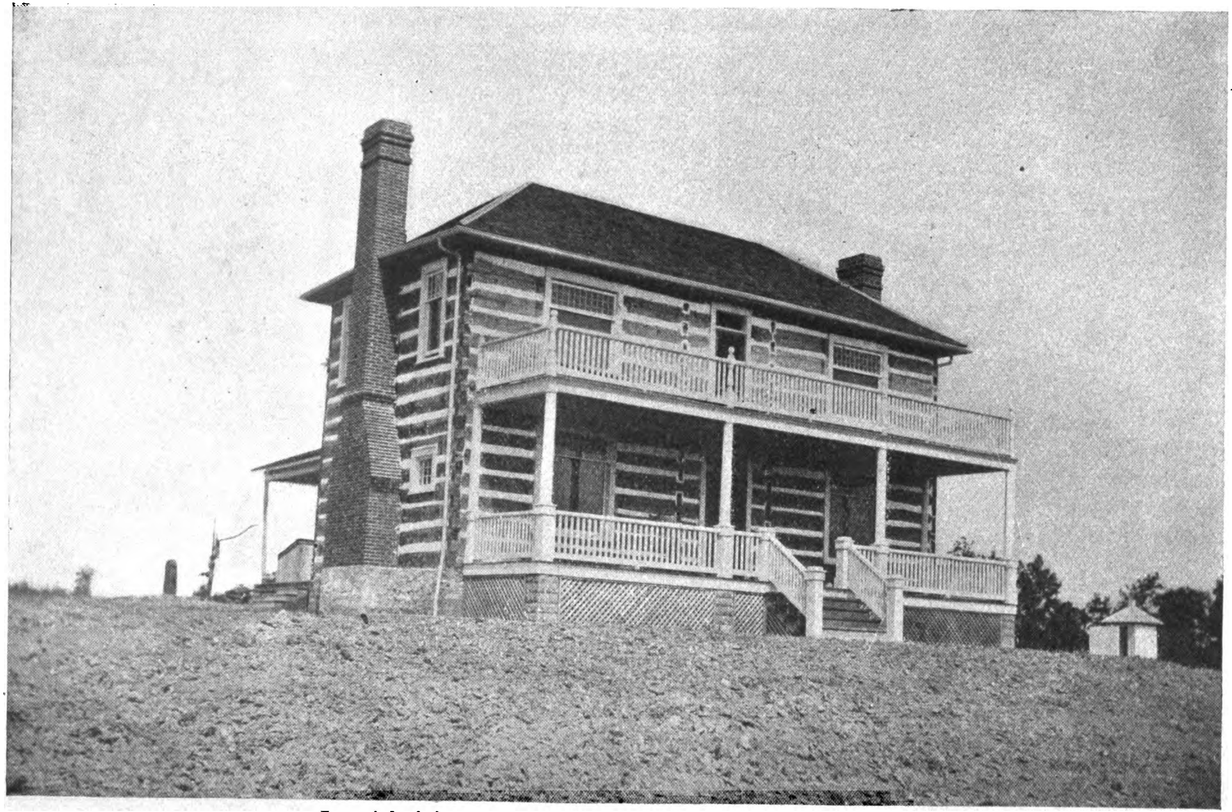


Fig. 29. Same planting as shown in Fig. 28. Note unevenness in growth of trees.



Log Administration Building at State Forest Reservation.

Report of Work Accomplished

AT THE STATE FOREST RESERVATION AND EXPERIMENTAL STATION, HENRYVILLE, CLARK COUNTY, INDIANA, TO DECEMBER 1, 1907.

Improvements.—The different improvements as: Custodian's residence and administration buildings, roadways, forest cleaning, field planting and field cultivation which were begun three years ago have been advanced to almost completion this past year.

The new log residence and administration building for the use of the Board and Custodian is fully completed and occupied. This structure is of hewed oak logs and simply well chinked and daubed and contains six large rooms, and therefore ample for the needs. By the use of sliding partitions eight rooms may be made. The building is fitted with a fifty candle power acetylene gas plant apparatus for illumination, with extensions for outbuildings when needed in the future. Concrete walks were built and cistern and well dug and fully completed in good style. A splendid barn suitable for six horses, and also outbuildings, were completed. The accommodations which were so sadly needed are now satisfactorily arranged conveniently to railway accommodations. The Indianapolis and Louisville Electric Railway now operating crosses the eastern border of the lands of the Reservation and a permanent station stop for the convenience of the public and Institution travel has been arranged near the headquarters buildings. By this arrangement visitors may come and go at any hour of the day.

The buildings at the northwest and south central parts of the Reservation which were contemplated by the Board and provided for with appropriations by the General Assembly of 1905, were abandoned and the money so appropriated was unexpended. The Board considered that this was a prudent thing to do inasmuch as more money became necessary for the improvements northeast than were expected at the time of taking up the work there. The idea was to centralize the building expense upon the northeast part of the Reservation and abandon the other improvements until such a time as made them more necessary.

The road building which has been in progress also for the past

three years was very greatly advanced this past year. The system of roadways extending across the Reservation and connecting the old and the new administration buildings and affording a connection route with the public highways extending along the eastern and southern borders was greatly improved by grading, drainage and gravelling. Another year will find this system of roadways in a splendid condition for all year use. These roads must be made in good condition or hauling cannot be done upon them during winter and rainy times of the year, and consequently this work will be extended at every opportunity until completed.

The forest cleaning was continued throughout last winter from December 1st to March 1st. At the latter date the work of pruning and cutting was discontinued until last August, when the work was resumed, and will be continued the remainder of the winter until spring. Nothing of cutting and pruning in forest cleaning is performed during the period of time from March 1st to August 1st, because of the sap season which occasions intense sprouting, the souring and rotting of the timber and the increased stimulus for attacks of beetles, borers and other forest insects. The same plans of cleaning and sale of product as that of former years are followed. (See pages 19-21, Fifth Annual Report.)

The field planting to trees and seeds as outlined in last year's report (page 25), was completed as fully as planned. The results of growth the past year were far in advance of any former ones, because of the most excellent growing conditions prevailing. It is the aim to complete the first planting of the fields this fall and next spring. Future tree and seed plantings will then be confined to replanting vacancies that may occur in the fields and to restocking the sparsely covered woodlands as they shall require.

The State nursery features, as outlined at the time of the origin of the Reservation and Experimental Station, are now getting well developed, and it is hoped to be able to distribute a good many trees the coming year. This feature has not been reached as soon as it could have been, for the reason that it was deemed advisable to use the nursery stock toward completing the plantings at the Station first, and get it in such a stage of advancement as to receive recognition from the experimental consideration first, and then take up the tree distribution. There is now growing at the Station a good amount of nursery stock and it will be sent out as soon as ready to those desiring it. The aim will be to distribute generally and not so as to interfere with the legitimate and rightful nursery trade and business. It will be conducted in the interest of all concerned

and rather to stimulate the nursery business than hinder it. The end sought will be increased interest and desire to secure and plant more trees.

The experimental forestry attempts at the Reservation are far better than was predicted by those who questioned and were not enthusiastic over the project of the State's making the effort. It is firmly believed by those who are familiar and in sympathy with the forestry movement, that the greatest good will result to posterity by the State's endorsement and engagement in experimental conduct for the education of its generations in the subject of forestry.

As evidence of the successful forestry attempts the following statistical tabulations by E. E. Davis, of Wabash College, and taken at the Experimental Station under the direction of the Superintendent the past summer, are here submitted after the following economic discussion:

THE ECONOMIC PROBLEM AND SOME EXPERIMENTS.

At the time of the establishment of the Forest Reservation and Forestry Experimental Station in Clark County, 1903, by the State Board of Forestry, the objects of the institution were fully stated by the press, and also in the annual reports mailed from the office of the Board. Also, throughout the time of the agitation and the obtaining of the legislative enactment to secure the land purchase and the accompanying appropriations, the aims and objects were fully stated as the demonstration of practical forestry upon the cheap, broken nonagricultural lands so abundant in the southern half of the State. The foundation principle was the idea of economy and industrial good by utilizing the more than 600,000 acres of such lands for the production of wood product for the use of the manufacturing industries, which land is most admirably adapted to timber growing, but is not so devoted under a system of sylviculture, but is left to waste and destruction.

At the very inception of the project the Board sincerely believed that forestry was an essential and vital element in such an economic consideration.- To that end the land was sought, secured and is being devoted, and the Board sees no cause for changing its plans and conclusions formed at that time.*

The tract of land secured was the best type of such land that

*See "Circulars" Nos. 97, 116 and 52, by the United States Department of Agriculture, and the article by the "Indianapolis Morning Star" of date October 28, 1907, all of which are published elsewhere in this report. These publications treat directly of this economic problem fully as was in the minds of the Board at that time. Also see Annual Reports by the Board of Forestry, 1903-1906.

could be found (see p. 27, Report 1905, and pp. 19-26, Report 1903). The following experiments of tree growing upon such lands and which were taken at the Forestry Experimental Station, as shown by the tabulations following this discussion, indicate that such lands are well suited to practical forestry enterprise. Germany has satisfactorily worked out forestry experiments upon such lands under its government and the statements following are facts from German foresters who know what they are saying:

The average wood production upon such nonagricultural lands, when not grown under a sylvicultural system, is 10 cubic feet per acre annually, or 80 B. M., which at the average price of lumber, \$15.00 per M = \$1.20 annual increment value per acre. Under systematic management such lands can be made to produce annually 40 cubic feet of wood or 320 B. M., which at the average price of lumber, \$15.00 = \$4.80 increment value per acre. These statements must not be taken as idle speculations, but as facts, and should appeal to individuals, corporations and governments for investment projects of splendid merit.

At the above ratios the waste lands of Indiana have the following possible values if devoted to forestry uses, besides the industrial good resulting from a stable wood product supply for manufacturing interests and labor:

Six hundred thousand acres uncultivated at 10 cubic feet per acre = 6,000,000 cubic feet or 48,000,000 B. M. at the average price of lumber, \$15.00 per M = \$720,000.00 annual increment value.

Six hundred thousand acres cultivated at 40 cubic feet per acre = 24,000,000 cubic feet or 192,000,000 B. M. at the average price of lumber, \$15.00 per M = \$2,880,000.00. A difference of \$2,160,000.00 to pay for the systematic control of such lands, besides a quantity of 144,000,000 B. M. in product.

It was upon such a basis of reasoning that the Board decided the plan of object lessons in practical forestry that it is now conducting, well knowing it to be the surest way to establish the principles of forestry in the minds of the citizens of the State, and further believing that if its ideas were backed by facts of completed forestry experiments that such lands which are now almost idle waste would, in course of time, be sought for forestry investments and the economic problem of wood supply for the industries and the utilization of such lands to the greatest advantage would be solved.

In these conclusions the Board fully appreciated the fact that years of time, the greatest patience and a most devoted perseverance would be necessary, but it believes that all its conclusions are both

probable and possible. It remains for the people to determine whether to act for its own welfare and that of the future. Such a course of philanthropic conduct is due as an element of justice to future generations by the present.

The economic features herein are the same as now promulgated by the National Department of Forestry in its efforts to obtain governmental control of the Appalachian highlands. (For a full discussion of the same see Circulars 97 and 116, by U. S. Department, pp. 132 and 147.)

Without a further discussion of the possibility of forest growing upon the cheaper lands and its industrial value the Board calls attention to the following tabulations by E. E. Davis, of Wabash College, which were taken at the Forest Reservation in Clark County, under the direction of the superintendent. These experiments are the first statistics taken of the attempts and indicate the success so far. It is the aim to retake the measurements in the course of five years and make the comparative estimates to show the increment of wood per acre. More and larger areas were not taken, because of the expense connected in view of the limited funds for office expenses allotted the department. The areas given are typical sections of the whole of which the part taken belongs. Not all the experiments in progress were taken because of the lack of means to conduct the work. Many areas were omitted at this time, but will be taken up next year.

Plat No. 1 is an experiment of reforesting an open field to American ash from seed planting. This field was consecutively farmed for more than fifteen years and until all traces of forest humus were gone. The field was regularly prepared as for corn planting and the seeds drilled thickly in rows during November, 1904 (see Fourth Annual Report, 1904, page 16, planting 6). This planting was given but limited cultivation. The fall of 1906 all the seedlings were dug and transplanted to other fields, except the stand retained as shown by the tabulations which were left to form a permanent forest stand.

Soil loose, porous, sandy clay. Elevation, 520 feet. Approximate trees per acre 1,720.

Plat No. 1. One-fourth Acre White Ash Seedlings.

Line 1 N. W. 80 2.5 chains.
Line 2 S. W. 10 2 chains.
Line 3 N. W. 42 3.25 chains, 1 link.

Height in Inches.	Straight Stem to Top.	Forked Stem.	Height, Inches to Fork.	Seconds.
10	2	..	..	..
11	1	..	..	..
13	1	..	..	..
15	5	..	..	..
17	2	1	12	..
18	5	..	..	..
19	1	..	..	..
20	3	1	16	1
21	7	..	..	..
22	5	..	..	..
23	5	..	..	..
24	4	2	6, 10	1
25	9	..	..	..
26	4	..	..	..
27	11	1	17	..
28	7	..	..	1
29	4	..	..	..
30	2	..	..	1
31	9	..	..	..
32	8	1	20	..
33	8	..	23, 17	..
34	11	..	..	..
35	9	1	20	..
36	19	1	19	2
37	15	2	13, 19	2
38	13	..	..	..
39	15	..	..	2
40	13	3	25, 25, 15	..
41	9	..	..	..
42	19	1	19	1
43	12	..	..	..
44	10	1	20	1
45	8	2	20, 20	..
46	12	1	39	..
47	12	..	..	..

Height in Inches.	Straight Stem to Top.	Forked Stem.	Height. Inches to Fork.	Seconds.
48	13	1	25	..
49	9	..	..	..
50	14	1	24	1
51	11	2	27, 15	1
52	11	1	40	1
53	7	..	..	..
54	5	1	24	..
55	5	1	41	1
56	5	3	41, 44, 27	..
57	9	1	27	..
58	4	1	28	..
59	1	1	35	..
60	4	1	31	..
61	4	..	..	..
62	3	..	..	..
63	1	..	..	..
64	2	..	..	..
65	..	..	..	..
66	..	..	..	..
67	..	..	..	..
68	1	..	..	..
69	..	..	..	..
70	2	..	..	..
71	..	..	..	..
72	1	..	..	..
	382	32		16

Total 430

Plat No. 2 is an experiment at reforesting an old field to mixed oak by planting the acorns. This field is the same as indicated in plat No. 1, ash planting, and planted at same time and in same manner. The treatment is the same throughout for both plantings, and all the soil conditions are the same. This experiment shows a far less growth rate and tree stand. Damping off was very great and was even so the past summer. The results from transplanting oak seedlings are bad and indicate the oaks must be grown from seed planted where it is aimed for the tree to grow.

The approximate trees per acre 836, which is not at all discouraging for oak propagation on old fields. It must be remembered, however, that a small oak seedling 6 or 8 inches high of stem may have a root from 3 to 5 feet long and almost a load for a man to carry. They grow slowly and scrubby until the root foundation is established.

Plat No. 2. One-half Acre Mixed Oak Seedlings.

Line 1 N. E. 10 2.5 chains.
Line 2 N. W. 80 2 chains.
Line 3 N. E. 10 2.5 chains.
Line 4 N. W. 80 2 chains.

Height in Inches.	Prime.	Seconds.
5	5	1
6	9	2
7	12	2
8	17	3
9	19	2
10	18	3
11	13	3
12	22	4
13	19	3
14	20	1
15	17	2
16	19	1
17	14	2
18	19	1
19	8	2
20	14	5
21	11	1
22	13	2
23	6	..
24	11	1
25	14	1
26	13	3
27	12	4
28	5	1
29	4	..
30	7	1
31	8	1
32	3	..
33	8	2
34	5	..
35	2	..
37	5	..
38	4	..
40	2	..
42	4	..
43	1	..
46	1	..
	384	54
Total		418

Plat No. 3 is an experiment at reforesting an old field to tulip poplar by transplanting upon it seedlings of one year's growth and of 15 to 24 inches height. These seedlings were purchased in Tennessee from a locality having similar soil characteristics to that of the area planted. They were secured in the fall of 1906 and stored over the winter and planted early in April, 1907. At time of planting a mule team and plow were used to make a wide, deep furrow across the field. Men with arm loads of trees followed and placed them, drawing dirt with their feet upon the roots to hold them in place and then a mule and plow completed the covering by turning a furrow of dirt upon them from both sides. It became necessary to straighten up and rearrange some of them after covering with the plow. Three men and a team can plant 4,000 seedlings per day in this manner.

The result of this work to date is almost perfect, as not 25 trees out of 20,000 planted in this field failed of growing this summer, and all indications point to their continuance. Soil porous, sandy and gravelly loose clay; 520 feet elevation and natural rolling drainage. Approximate trees per acre 1,718.

Note.—Twenty thousand American ash were planted in same manner and the results are equally as good.

Plat No. 3. Tulip Poplars. Seedlings Planted, Spring 1907. One-half Acre.

Line 1 S. E. 24 2.5 chains.
Line 2 S. W. 56 2 chains.
Line 3 S. E. 24 2.5 chains.
Line 4 S. W. 56 2 chains.

Height, Inches.	Terminal buds and stems damaged by shipping improperly and thus had to be cut back at planting.	Trees not Damaged in Shipping.
5	36	..
6	32	..
7	28	..
8	38	..
9	45	..
10	53	..
11	53	..
12	63	1
13	63	..
14	59	1
15	55	2
16	61	3
17	46	4
18	40	7
19	36	8
20	29	3
21	16	6
22	15	11
23	13	5
24	14	3
25	10	9
26	5	1
27	5	1
28	5	..
29	4	3
30	3	1
31	..	..
32	..	..
33	..	1
34	..	..
35	..	..
36	..	..
37	..	..
38	1	1
	788	71
Total		859

Plat No. 4 is an experiment at reforesting an old open field with black walnut by planting the seed. This field was planted in the fall of 1905. (See Fifth Annual Report, page 20.) The missing places were filled in this last spring, 1907, by planting American ash seedlings. The soil and conditions are same as given for plat No. 8.

Approximate trees per acre, 1,774.

Plat No. 4. Black Walnut, filled in with White Ash. One-half Acre.

Line 1 S. W. 13 2.5 chains.

Line 2 N. W. 77 2 chains.

Line 3 S. W. 13 2.5 chains.

Line 4 N. W. 77 2 chains.

Height, Inches.	Walnut. Total–H.	Stem–Sec.	Ash. Total–H.	Stem–Sec.
5	5	..	..	..
6	4	..	..	..
7	10	..	..	..
8	16	1	..	..
9	27	1	1	..
10	28	2	..	..
11	31	3	..	1
12	26	..	1	..
13	29	..	..	..
14	30	1	3	..
15	32	1	5	..
16	25	..	9	..
17	34	1	2	..
18	31	5	14	2
19	35	1	13	1
20	32	4	16	2
21	27	..	12	..
22	23	1	15	..
23	25	..	8	..
24	31	2	9	1
25	24	..	11	1
26	13	..	12	..
27	11	..	13	2
28	10	..	7	..
29	7	..	11	..
30	6	..	11	..
31	5	..	9	..
32	3	..	7	..
33	1	..	5	..
34	..	..	10	..
35	..	..	9	..
36	..	..	7	..
37	2	..	6	..
38	1	..	7	..
39	..	..	4	..
40	..	..	5	..
41	..	..	2	..
42	..	..	5	..
43	..	..	1	..
44	..	..	3	..
45	..	..	4	..
	584	23	271	9
Total				887

Plat No. 5 is an experimental planting for the same purpose as that of No. 4, and planted the fall of 1904, but on a field with different drainage and soil conditions. The soil of this field is less sandy, gravelly and porous and is low, level in drainage and consequently the trees have not done so well. Owing to the wet condition of the soil grass sod has formed and made cultivation more difficult and the growth of the trees has not been so good.

Elevation 520 feet. Average trees per acre, 1,536.

Plat No. 5. Black Walnut. One-half Acre; Pure Stand.

Line 1 N. W. 38 2 chains.
Line 2 S. W. 52 2.5 chains.
Line 3 N. W. 38 2 chains.
Line 4 S. W. 52 2.5 chains.

Height, Inches.	Straight Stem–H.	Forked Stem, Total–H.	Stem to Fork.	Sec.
5	68	..	12	2
6	44	..	11	1
7	70	2	17	2
8	102	4	9	3
9	116	7	18	4
10	74	3	11	2
11	70	7	10	1
12	62	18	5	2
13	40	9	5	2
14	31	4	4	..
15	28	10	2	..
16	23	9	3	1
17	16	9	..	1
18	12	1	1	1
19	8	4	1	1
20	11	6	..	..
21	10	1	1	1
22	2	3	..	..
23	4	..	..	..
24	4	2	..	..
25	5	..	..	..
26	5	3	..	..
27	..	..	..	..
28	..	2	..	..
29	3	..	..	..
30	..	1	..	..
31	1	2	..	..
32	1	..	..	..
33	..	..	..	..
34	..	1	..	..
35	1	..	..	..
36	1	..	..	..
37	2	..	..	..
42	1	..	..	..
45	..	1	..	..
	635	109		24
Total				768

Plats "6A" and "6B" are experiments of the natural reproduction of hardwoods upon an abandoned new-ground field which was cultivated to corn and tomatoes jointly during three seasons and last during the summer of 1903. When the crop was removed it was permitted naturally to grow up to trees. This last September, 1907, it was given the forest cultivation clearing. The tabulations given in the tables, "6A" and "6B," show the prime stand of trees retained at cultivation. The count was taken in two different parts of the field and shows an average of **1,135 trees per acre.**

Soil, porous sandstone clay. Elevation, 590 feet. Natural rolling surface drainage.

Plat No. 6A. Natural Reproduction Hardwoods. One-half Acre.

Line 1 W. 1 N. 2.5 chains.
Line 2 S. 1 E. 2 chains.
Line 3 W. 1 N. 2.5 chains.
Line 4 S. 1 E. 2 chains.

Height, Feet.	Oak.	Hickory.	Walnut.	Maple and Ash, Mixed.	Gum.
2	..	2	..	..	..
2.5	1	1	1	..	..
3	..	16	2	..	1
3.5	1	17	2	..	..
4	7	44	..	..	..
4.5	3	51	1	..	1
5	11	67	3	2	1
5.5	8	35	1	..	2
6	10	40	..	..	..
6.5	12	22	..	..	..
7	15	15	2	1	1
7.5	14	6	1	..	2
8	25	3	..	..	2
8.5	5	..	..	1	..
9	7	2	..	1	..
9.5	8	..	..	..	..
10	7	..	..	..	..
10.5	3	..	..	1	1
11	2	..	..	..	..
11.5	1	..	..	..	..
12	3	..	..	..	..
	143	321	13	6	11
Total					494

Plat No. 6B. Natural Reproduction Hardwoods. One-half Acre.

Line 1 N. 13 W.
Line 2 W. 13 N.
Line 3 N. 13 W.
Line 4 W. 13 N.

Height, Feet.	Oak.	Hickory.	Walnut.	Gum.	Mixed.
1	..	..	..	..	..
1.5	..	2	..	..	..
2	..	4	..	..	..
2.5	..	8	..	..	..
3	2	4	1	..	..
3.5	1	8	..	..	1
4	3	33	..	..	2
4.5	7	46	..	1	..
5	14	60	1	1	..
5.5	18	50	2	..	..
6	25	43	1	1	2
6.5	22	43	..	..	1
7	31	36	..	1	..
7.5	19	15	1	..	1
8	30	11	..	..	..
8.5	14	2	..	..	..
9	17	1	..	..	..
9.5	16	..	..	..	..
10	6	..	..	..	1
10.5	10	..	..	..	2
11	6	..	..	..	..
11.5	3	..	..	..	..
12	7	..	..	..	..
13.5	3	..	..	..	..
15	1	..	..	..	..
	255	366	6	4	10
Total					641

Plat No. 7 is an experiment for natural reforestation upon a tract of fire-burned area which was cleared off after being burned over and then left, to reforest naturally.

The area of which this is a part was burned over in 1902 and cleared off the winter of 1903. The soil of this tract is hard sandstone clay and of 670 feet elevation. Approximate trees per acre, 1,618.

Plat No. 7. One-half Acre.

Line 1 N. W. 34 2 chains.
Line 2 N. E. 56 2.5 chains.
Line 3 N. W. 34 2 chains.
Line 4 N. E. 56 2.5 chains.

Height, Feet.	Oak.	Hickory.	Maple.
2	..	3	..
2.5	..	2	..
3	..	2	..
3.5	..	3	..
4	2	8	..
4.5	1	16	1
5	..	19	..
5.5	7	24	..
6	7	29	1
6.5	11	33	..
7	16	47	1
7.5	13	53	2
8	22	54	..
8.5	19	43	1
9	31	33	..
9.5	24	24	..
10	40	28	2
10.5	27	18	1
11	23	11	3
11.5	20	5	2
12	20	1	3
12.5	6	4	..
13	9	1	..
13.5	3	..	..
14	8	..	..
14.5	5	..	..
15	9	..	..
15.5	4	..	..
17	2	..	..
18	2	..	..
	331	461	17
Total			809

Plat No. 8A and 8B indicate the tree stand upon a tract of natural woodland which was given the forest cultivation treatment during the fall of 1904. At that time it was a mat of jungle and devastated forest as the result of complete and reckless timber cutting. In this forest cultivation all the inferior trees were removed and the rubbish piled in heaps so the sun light could penetrate to the soil and induce a new growth. Table 8A shows the upper stand retained at time of cultivation. Table 8B shows the new growth since cultivation springing from seeds lying dormant in the forest humus and only needing growing conditions.

Soil, hard sandstone clay, 620 feet elevation, and natural rolling surface drainage. Total trees per acre, 1,486.

Plat No. 8A. One Acre. Upper Species.

Diam., Inches.	White Oak.	Height in Feet 25	30	35	40	45	50	55	60	65	70	75	80
3	20	8	9	3	..	..	..	..	..	..	..	..	..
4	29	2	6	8	8	2	3	..	..	..	..	..	..
5	29	..	7	5	7	4	5	1	..	..	..	..	..
6	14	..	..	1	1	3	3	5	1	..	..	..	..
7	17	..	..	..	..	2	3	5	5	1	1	..	..
8	8	..	..	..	..	..	..	4	3	1	..	..	..
9	..	..	..	..	..	..	..	..	..	..	..	..	..
10	1	..	..	..	..	..	..	..	..	1	..	..	..
11	2	..	..	..	..	..	1	..	..	1	..	..	..
	120												
	Black Oak.												
3	1	..	..	1	..	..	..	..	..	..	..	..	..
4	..	..	..	..	..	..	..	..	..	..	..	..	..
5	1	..	..	..	..	..	..	1	..	..	..	..	..
6	12	..	..	..	..	..	1	3	1	3	3	1	..
7	13	..	..	..	..	..	..	1	3	4	1	4	..
8	12	..	..	..	..	..	..	..	7	2	1	1	1
9	5	..	..	..	..	..	..	..	2	..	1	2	..
10	3	..	..	..	..	..	..	..	..	2	1	..	..
11	1	..	..	..	..	..	..	..	..	..	..	1	..
13	1	..	..	..	..	..	..	..	..	1	..	..	..
14	1	..	..	..	..	..	..	..	..	..	..	1	..
18	1	..	..	..	..	..	..	..	..	..	..	..	1
	51												
	Red Oak.												
3	..	..	..	..	..	..	..	..	..	..	..	..	..
4	..	..	..	..	..	..	..	..	..	..	..	..	..
5	4	..	..	..	..	..	..	1	1	1	..	1	..
6	4	..	..	..	..	..	1	1	..	1	..	1	..
7	3	..	..	..	..	..	..	..	..	..	2	1	..
8	2	..	..	..	..	..	..	..	1	..	..	1	..
9	3	..	..	..	..	..	..	..	1	1	..	1	..
15	1	..	..	..	..	..	..	..	..	..	..	1	..
	17												

Diam., Inches.		Height in Feet											
	Black Gum.	25	30	35	40	45	50	55	60	65	70	75	80
5	1	..	..	..	1	..	..	..	..	..	..	..	..
14	1	..	..	..	..	..	..	..	..	..	..	..	1
20	1	..	..	..	..	..	..	..	..	..	..	..	1
	3												
	Maple.												
3	2	..	1	..	1	..	..	..	..	..	..	..	..
4	1	..	1	..	..	..	..	..	..	..	..	..	..
6	2	..	..	..	1	..	..	1	..	..	..	..	..
	5												
	Hickory.												
4	2	..	2	..	..	..	..	..	..	..	..	..	..
6	1	..	..	..	..	..	..	1	..	..	..	..	..
7	1	..	..	..	..	..	..	1	..	..	..	..	..
	4												
	Beech.												
4	1	..	1	..	..	..	..	..	..	..	..	..	..
		10	27	18	19	11	17	25	25	19	10	16	4
Total trees													201

Plat 8B. Lower Story Species. One Acre.

Line 1 N. W. 37 3 chains 16.062 links.
Line 2 S. W. 53.
Line 3 N. W. 37.
Line 4 S. W. 53.

Height. Feet.	Oak.	Hickory.	Gum.	Mixed—Tulip, Maple, Beech, Chestnut.
1	36	83	10	8
1.5	41	95	24	8
2	63	130	34	19
2.5	36	53	30	30
3	34	42	44	13
3.5	22	30	31	21
4	20	20	36	18
4.5	17	16	17	15
5	12	16	8	15
5.5	8	7	3	4
6	8	6	4	3
6.5	5	8	1	2
7	..	8	..	3
7.5	..	8	1	1
8	..	6	..	3
8.5	1	6	..	..
9	..	2	..	1
9.5	..	1	..	..
10	..	2	..	..
10.5	..	4	..	2
11.5	..	2	..	..
12	..	1	..	..
12.5	..	1	..	..
13	1	..	2	..
13.5	..	3	..	..
14	2	..	..	..
14.5	..	1	..	..
15	6	..	..	2
15.5	4	2	..	..
16	3	..	..	..
17	1	..	..	..
17.5	1	..	..	..
18	2	..	..	1
19	1	..	..	..
20	11	..	..	3
	335	533	245	172
Total				1,285

Plat No. 9 "A" and "B" is an experiment at obtaining a second story or undergrowth of trees beneath a top or larger growth. The area of which "A" and "B" are a part was given the forest cleaning the fall of 1905. This tract was so badly devastated that at the completion of the cleaning cultivation scarcely anything remained, but the second story growth as shown by "A" is very good. There is danger of the soils when too much exposed to the sun of burning out and the second story forest does not materialize. This tract is on blue sandstone clay of hard compact form and with an elevation of 650 feet.

Plat No. 9. One Acre.

Line 1 N. E. 30 3 chains 16.062 links.
Line 2 S. E. 60.
Line 3 N. E. 30.
Line 4 S. E. 0.

A. *Lower Growth.*

Height, Feet.	Hickory.	Oak.	Other Species.	Total.
3	32	34	7	..
4	21	52	25	..
5	18	48	22	..
6	53	37	12	..
7	85	28	4	..
8	103	32	2	..
9	129	23	4	..
10	94	14	2	..
11	86	7	1	..
12	79	9	4	..
13	16	5	2	..
14	4	4	..	..
15	1	4	1	..
16	..	..	..	..
17	..	2	..	..
	761	299	86	1,146
				80
Upper and lower growth.				1,226

B. *Upper Growth.*

Diam.. In.	Hickory.	Oak.	Gum.	Total.
2	..	5	..	..
3	1	5	..	..
4	2	8	..	..
5	1	13	..	..
6	2	4	..	..
7	2	12	..	..
8	..	8	..	..
9	2	5	..	..
10	..	1	..	..
11	..	2	..	..
12	..	1	..	..
13	..	2	..	..
14	..	1	..	..
15	..	..	..	..
16	..	1	..	..
17	..	..	..	..
18	..	..	1	..
19	..	..	..	..
20	..	..	..	..
24	..	1	..	..
	10	69	1	80

Plat No. 10 is an experiment giving the number of standing hardwood trees per acre after the forest cleaning was applied. There has been near 380 acres so treated and this experimental tract is an average for the lot. This forms the upper story forest and will be removed when it attains a suitable commercial size and the lower story forest indicated which follows the cultivation will succeed it and so on forest perpetuation is accomplished on such lands.

Plat No. 10. One Acre. Old Growth.

Line 1 S. W. 55 3 chains 16.062 links.
Line 2 N. W. 35.
Line 3 S. W. 55.
Line 4 N. W. 35.

Dia., In.	White Oak.	Black Oak.	Red Oak.	Ches. Oak.	Hickory.	Gum.	Pine.	Total.
2	48	3	1	17	3	..	..	72
3	40	8	3	21	1	..	..	73
4	32	10	..	23	1	1	..	67
5	11	10	1	15	..	..	..	37
6	7	4	3	10	3	..	..	27
7	4	8	1	10	1	..	1	25
8	1	8	1	5	2	..	1	18
9	2	2	2	3	5	..	..	14
10	..	1	..	..	2	..	..	3
11	..	..	..	2	2	..	..	4
12	1	1	..	..	1	..	..	3
13	..	..	..	..	1	..	..	1
14	..	..	..	..	..	..	..	..
15	..	..	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..
17	..	..	..	..	..	..	..	..
18	..	1	..	..	..	..	..	1
	146	56	12	106	22	1	2	345

Plat No. 11 is an experiment at natural reforestation upon a tract cleared off and farmed two seasons to corn and then permitted to grow up. The area of which this plat is a part was last farmed in 1901. It was given the forest cultivation in the winter of 1904. The tabulations show the result. This area has hard blue sandstone clay soil and elevation 620 feet. Drainage natural rolling. Approximate trees per acre, 2,998.

Plat No. 11. One-half Acre Natural Reproduction in Abandoned Field.

Line 1 S. W. 54 2.5 chains.
Line 2 N. W. 36 2 chains.
Line 3 S. W. 54 2.5 chains.
Line 4 N. W. 36 2 chains.

Height, Feet.	Oak.	Chestnut.	Gum.	Mixed.	Hickory.
4	6	..	1	..	33
5	16	..	7	1	67
6	16	..	5	3	105
7	37	2	7	7	129
8	56	..	5	6	170
9	34	1	3	5	129
10	51	2	2	5	87
11	55	1	4	2	97
12	80	5	5	3	71
13	55	2	..	..	14
14	35	3	..	2	8
15	30	..	..	..	1
16	10	..	..	..	..
17	7	..	..	..	..
18	9	..	..	..	..
19	1	..	..	..	..
20	1	..	..	..	..
	499	16	39	34	911
Total					1,499

Plat No. 12 shows an exceptionally good White Oak stand of trees upon a tract of natural forest which has been given the forest cultivation. The greater part of the land so cultivated possesses a good White Oak stand as shown in the tabulations. It is the predominating species throughout.

Elevation of plat No. 12 is 680 feet. Soil, blue sandstone clay.

Plat No. 12. One Acre. Woodland.

Line 1 S. E. 38 3 chains 16.062 links.
Line 2 N. W. 52.
Line 3 S. E. 38.
Line 4 N. W. 52.

Dia., Inches.	White Oak.	Black Oak.	Red Oak.	Hickory.	Other Species.	Total.
1	39	..	..	7	1	47
2	114	1	5	15	2	137
3	62	1	19	5	3	90
4	40	9	31	..	..	80
5	26	11	28	1	..	66
6	15	6	21	1	..	43
7	12	3	10	1	..	26
8	6	..	11	..	..	17
9	2	2	10	..	..	14
10	2	2	4	..	..	8
11	1	..	5	..	..	6
12	1	..	1	..	..	2
	320	35	144	30	6	535

Plat No. 13 is an experiment at reforesting a 40-acre field by mixed planting. This field is very good soil and has gently rolling surface. A variety of soils however, is found throughout the tract. The hickory, walnut and oak stands were obtained by planting the seeds upon the field in the fall of 1905 and the transplanting of the ash and elm seedlings was done last fall, 1906, and this last spring, 1907. This stand will be enriched by other plantings and natural growth as time will permit.

Elevation of this tract as a whole, 590 feet.

Plat No. 13. One Acre. Plantation.

Line 1 N. E. 65 3 chains 16.062 links.
Line 2 S. E. 25.
Line 3 N. E. 65.
Line 4 S. E. 25.

Height, Inches.	Hickory.	Ash.	Elm.	Gum.	Walnut.	Oak.
6	61	1	9	..	..	17
7	11	2	1	..	1	5
8	12	2	9	..	1	5
9	9	1	4	..	1	2
10	4	2	8	..	2	2
11	5	..	1	..	..	2
12	1	2	4	1	1	1
13	1	1	6	1	1	..
14	1	5	14	..	3	..
15	1	5	9	..	3	1
16	..	9	4	..	2	..
17	..	4	3	..	3	..
18	..	12	6	1	10	..
19	..	7	3	..	7	..
20	..	14	3	..	13	..
21	..	14	3	..	10	..
22	..	13	5	..	10	..
23	..	8	2	..	5	..
24	..	16	1	..	10	..
25	..	14	..	..	7	..
26	..	10	1	..	5	..
27	..	18	2	1	9	..
28	..	18	1	..	9	..
29	..	18	1	..	9	..
30	..	12	3	..	10	..
31	..	16	..	..	9	..
32	..	16	..	1	9	..
33	..	16	..	..	8	..
34	..	16	..	..	9	..
35	..	18	..	..	9	..
36	..	16	1	..	8	..
37	..	12	..	..	10	..
38	..	12	..	..	8	..
39	..	3	..	..	2	..
40	..	9	..	..	7	..
41	..	4	..	..	2	..
42	..	3	..	..	2	..
43	..	2	..	..	2	..
44	..	1	..	..	..	..
48	..	..	..	1	..	..
50	..	..	..	2	..	..
60	..	..	..	3	..	..
	106	352	104	11	217	35
Total						825

Plat No. 14 is an experiment of a tract of natural woodland which has been cultivated and shows the predominance of hickory in the stand. This tract is an example of an ordinary devastated jungle growth found upon the Reservation as well as throughout the 600,000 acres of hilly broken lands of southern Indiana and shows what is there for future forests if they are cultivated and not burned over.

The soil of this tract is heavy white and blue sandstone clay with natural rolling surface drainage. Elevation, 630 feet.

Plat No. 14. One Acre. Woodland.

Line 1 N. W. 39 4 chains.
Line 2 N. E. 51 2.5 chains.
Line 3 N. W. 39 4 chains.
Line 4 N. E. 51 2.5 chains.

Diam., Inches.	White Oak.	Red Oak.	Black Oak.	Hickory.	Other Species.	Total.
1	53	10	3	161	34	261
2	70	9	7	36	5	127
3	20	5	1	2	..	28
4	6	2	3	2	..	13
5	3	2	5	1	..	11
6	4	2	2	..	1	9
7	3	1	2	1	..	7
8	..	..	2	1	..	3
9	1	..	2	..	..	3
10	..	..	1	..	..	1
11	..	..	1	..	..	1
12	4	..	..	..	..	4
13	1	..	..	..	..	1
	165	31	29	204	40	469

Plat No. 15 is an experiment of natural forest growth on the slopes and base of knoblands. This area was a badly devastated one by fire and slaughter by careless cutting when the Reservation was purchased. In the fall of 1904 the area was thoroughly cultivated by forest cleaning as is conducted at the Reservation. The tabulation shows the variety of trees and sizes now growing. A peculiar thing about the entire knob-land forest growth is the variety of trees growing successfully upon them that are not at all considered adapted to them. Upon these lands Chestnut Oak and American Chestnut take the predominance over White Oak.

The soil of this area is purely sandstone clay of the hard shaley kind. Elevation, 820 feet. Surface broken ridges.

Plat No. 15. One-half Acre. Natural Growth.

Line 1. N. W. 47 2.5 chains.
Line 2 S. W. 43 2 chains.
Line 3 N. W. 47 2.5 chains.
Line 4 S. W. 43 2 chains.

Diam., In.	White Oak.	Black Oak.	Red Oak.	Ches. Oak.	Hickory.	Maple.	Quaking Aspen.	Chestnut.
1	36	31	25	93	43	22	1	51
2	34	14	31	155	11	24	4	31
3	11	1	6	70	..	2	3	6
4	4	..	1	24	..	1	1	2
5	..	1	..	2	..	1	..	3
6	..	..	..	3	..	..	..	2
7	..	..	..	4	..	..	..	..
8	1	..	..	..	..	..	..	..
9	..	..	..	2	..	..	..	..
10	..	..	..	1	..	..	..	1
11	..	..	..	1	..	..	..	..
12	..	..	..	1	1	..	..	..
13	..	..	..	..	..	..	..	..
14	..	1	..	..	..	..	..	..
15	..	..	..	..	..	..	..	..
16	..	..	..	..	1	..	..	..
17	..	..	..	1	..	..	..	..
18	..	..	..	1	..	..	..	..
19	..	..	..	..	..	..	..	..
20	..	..	..	..	..	1	..	..
	86	48	63	258	56	51	9	96
Total								667

Plat No. 16 is an experiment of a walnut planting at the base of the knob-lands upon a field cultivated for several years but not abandoned and which possessed a soil composition of porous sandy and gravelly clay suited to walnut growth and upon which field stood several good thrifty walnut trees. This field was planted to walnut seeds the spring of 1904 at distances of five feet apart and was given two plowings as cultivation per season until the past summer when they were not given any attention at all. This tract is surrounded on three sides by timbered land and consequently the squirrels disturbed the planting by digging up the walnuts and carrying them away. Thus the stand is not complete, but the acre given is the average for the tract of 6,000 trees in the planting which are growing at this time. (See Fourth Annual Report, 1904, page 12, Planting 1.)

Elevation of this tract, 700 feet. Natural rolling surface drainage.

Plat No. 16. Walnut Plantation. One Acre.

Line 1 W. 3 chains 16.062 links.
Line 2 S.
Line 3 W.
Line 4 S.

Height in Feet.	Trees.	Height in Feet.	Trees.
1	...	5	118
1.5	...	5.5	46
2	3	6	26
2.5	61	6.5	6
3	114	7	1
3.5	185		
4	254	Total	977
4.5	163		

Plat No. 17 is an experiment of natural forest growth same plan and purpose as in No. 15. This elevation, however, is about 850 feet and is in the altitude of coniferous trees. The knob-lands grow pine successfully and another characteristic is that the other species are abundant as shown by the tabulation. However, the pines are gradually giving way to the hardwoods which form the second story forest under them. A great many young pines are coming on and regeneration by pine seems possible.

Plat No. 17. One Acre.

Line 1 N. W. 57.3 chains 16.062 links.
Liue 2 N. E. 33.
Line 3 N. W. 57.
Line 4 N. E. 33.

Diam., In.	Ches. Oak.	White Oak.	Black Oak.	Red Oak.	Hickory.	Pine.	Other Species.
1	58	33	2	23	154	32	12
2	72	52	2	19	22	5	11
3	32	14	1	11	..	..	3
4	27	14	1	7	1	..	1
5	23	7	3	7	1	1	1
6	26	3	3	8	1	..	..
7	11	8	1	7	1	..	..
8	11	4	..	7	1	1	..
9	4	1	..	1	1	..	..
10	1	3	..	3	..	..	..
11	1	3	..	2	..	..	..
12	2	1	2	2	2	..	..
13	1	..	..	1	1	..	..
14	1	2	..	..	..	..	..
15	..	1	..	..	1	..	..
16	1	1	..	..	..	..	..
	271	147	15	98	186	39	28
Total							784

Plat No. 18 is an experiment in the hill lands showing the land after forest cleaning. This tract is located upon the badly broken ridges at base of knobs and somewhat upon the slopes. The elevation is 850 feet and the soil formation shaley sandstone clay. This tract is so broken that agricultural farming would not be at all successful, even if the soil were suitable, but the tree growth indicates that it can successfully be devoted to forestry. The stand given is that of all the good trees after all damaged and worthless kinds are removed. It would grow three or four times this number.

Plat No. 18. One-half Acre Natural Growth.

Line 1 N. W. 31 2.5 chains.
Line 2 S. W. 59 2 chains.
Line 3 N. W 31 2.5 chains.
Line 4 S. W. 59 2 chains.

Diam., In.	Ches. Oak.	White Oak.	Red Oak.	Black Oak.	Hick-ory.	Maple.	Chest-nut.	Gum.	Other Spec.
2	65	34	5	16	6	10	31	1	4
3	21	9	1	5	3	5	13	2	5
4	6	2	..	4	..	1	4	..	4
5	3	1	..	3	..	..	..	..	2
6	6	..	..	..	..	..	..	..	..
7	2	1	1	1	1	..	..	..	..
8	3	1	2	..	2	..	..	..	..
9	2	1	..	1	1	..	1	..	..
10	1	..	..	..	..	..	..	..	..
11	1	..	..	1	..	..	..	..	..
12	1	..	..	1	..	..	..	..	..
13	..	..	..	..	1	..	..	..	..
14	..	..	..	..	..	..	..	..	..
15	..	..	..	1	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..
17	..	..	..	..	..	..	..	..	..
18	..	..	..	..	..	..	..	..	..
19	..	..	..	..	..	..	..	2	..
	111	49	8	33	14	16	49	5	15
Total									300

Plat No. 19 is an experiment of natural forest growth upon the knoblands with an elevation of 1,000 feet. This tract was a mat of devastation and jungle treated to forest cultivation the winter of 1904. The tabulation shows the species that grow successfully. Indications at this time are good for the successful growing of the best hardwoods upon the knoblands. Time will tell the sizes and quality such timber trees will reach upon such elevation and soil. The soil of this region is sandstone clay and shale formation with the sandstone ledge rock outcropping numerously.

Plat No. 19. One Acre Natural Growth.

Line 1 N. E. 42 5 chains.
Line 2 N. W. 48 2 chains.
Line 3 N. E. 42 5 chains.
Line 4 N. W. 48 2 chains.

Diam., In.	Ches. Oak.	White Oak.	Red Oak.	Black Oak.	Hick-ory.	Pine.	Gum.	Maple.	Chest-nut.	Quaking Aspen.	Total
2	62	8	10	1	44	1	..	4	3	1	134
3	18	2	..	..	7	1	..	..	..	2	30
4	14	3	1	3	5	3	..	..	1	2	32
5	19	2	3	1	8	3	..	..	..	..	36
6	19	1	3	2	4	4	..	..	..	..	33
7	15	..	2	1	2	4	..	..	..	..	24
8	18	..	7	3	2	6	..	..	..	..	36
9	10	1	3	2	1	6	1	..	1	..	25
10	10	..	5	..	1	4	..	..	..	..	20
11	1	..	1	..	1	2	..	..	..	..	5
12	2	..	1	..	..	..	1	..	..	..	4
13	..	..	..	..	1	..	..	..	..	..	1
14	1	..	..	..	1	..	..	..	..	..	2
15	..	..	..	..	..	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..	..	..
17	..	..	..	..	2	..	..	..	..	..	2
18	..	..	..	..	..	..	..	..	..	..	..
19	..	..	..	..	..	..	..	..	..	..	..
20	..	..	1	..	..	..	..	..	..	..	1
	189	17	37	13	79	34	2	4	5	5	385

Arbor Day

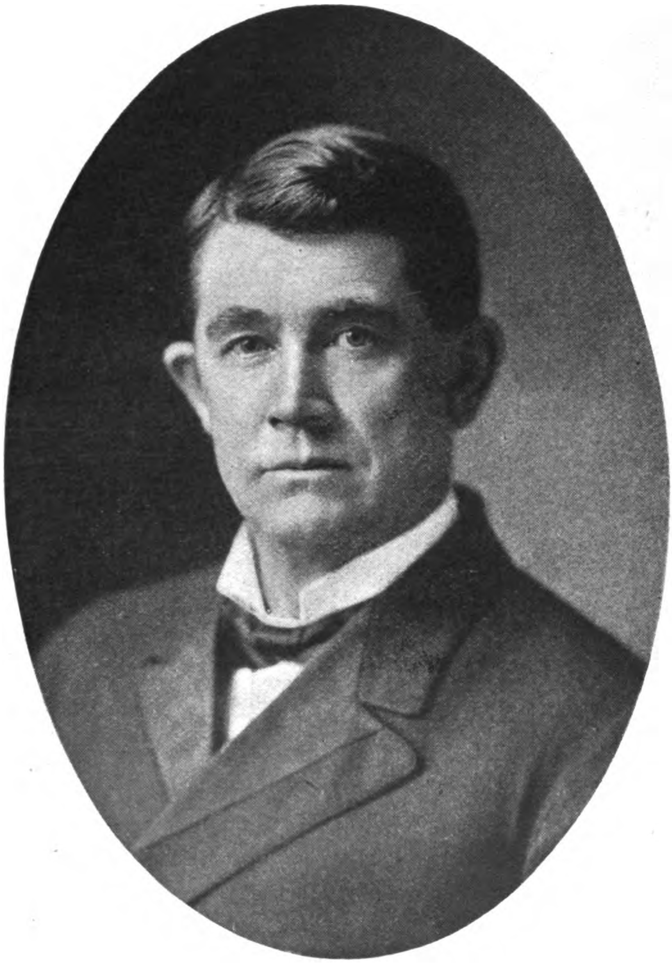
Woodman, Spare That Tree

Woodman, spare that tree,
  Touch not a single bough!
In youth it sheltered me,
  And I'll protect it now;
'Twas my forefather's hand
  That placed it near his cot;
There, woodman, let it stand,
  Thy axe shall harm it not.

That old familiar tree,
  Whose glory and renown
Are spread o'er land and sea—
  And would'st thou hack it down?
Woodman, forbear thy stroke,
  Cut not its earth-bound ties.
Oh, spare that aged oak,
  Now towering to the skies!

When but an idle boy,
  I sought its grateful shade;
In all their gushing joy,
  Here, too, my sisters played.
My mother kissed me here;
  My father pressed my hand—
Forgive the foolish tear;
  But let the old oak stand.

My heart-strings round thee cling,
  Close as thy bark, old friend;
Here shall the wild birds sing,
  And still thy branches bend.
Old tree! the storm still brave,
  And, woodman, leave the spot!
While I've a hand to save,
  Thy axe shall harm it not.



Governor J. Frank Hanly.

Proclamation by the Governor

UNITED STATES OF AMERICA.
STATE OF INDIANA.
EXECUTIVE DEPARTMENT.

A PROCLAMATION.

The mysteries of the changing seasons are about us. Budding foliage, bursting flowers and fragrant blossoms are everywhere. The air is vibrant with the babble of many waters and with the cries and songs of nestling birds. April—changing, fickle, winsome April—sits again "At the loom of Spring," weaving of air and sunlight and of dew and shower a thousand "wonder fabrics." Unseen but vital and mysterious forces are revivifying the earth and calling unto us to join in Nature's annual triumph over death.

To this call we can make no more appropriate answer than to set apart a day for the celebration of the return of this glad new season, and for the planting of trees and shrubs. Every tree planted makes the earth more habitable and a happier place in which to dwell. It adds, also, to the material welfare of the State.

Therefore, in accordance with precedent and custom, and in keeping with the moving and impelling forces about us, I, J. Frank Hanly, Governor of the State of Indiana, do hereby designate, set apart and proclaim Friday, April 26, and Friday, October 25, 1907, as

ARBOR DAYS

and recommend that each of said days be observed by the people of the Commonwealth as a day of rest and celebration; that the ceremonies incident to the celebration of these days be characterized by the planting of trees and shrubs upon the grounds about public buildings and public institutions, upon the public highways and about private homes; that those in charge of the benevolent institutions of the State give recognition to these days by fitting observance, and that the schools, public and private, observe them, as far as practicable, by public exercises of such a character as will give the children of the State a better understanding and a higher appreciation of tree and bird life.

Let this be done in the interest of forestry cultivation, and with a view to adding to the beauty and the wealth and resources of the State, and to our own culture and happiness and the culture and happiness of our children. To him who understands the life of tree and bird and the lessons taught by them "the whispering grove a holy temple is," and every bird that has the gift of song, God's messenger.

Done at the capitol of Indiana, in the city of Indianapolis, this sixteenth day of April, in the year of our Lord, nineteen hundred and seven, in the year of the independence of the United States the 131st and of the State of Indiana the 91st.

J. FRANK HANLY,
Governor of Indiana.

By the Governor:
FRED A. SIMS,
Secretary of State.
[SEAL]

Message to Schools

President Roosevelt addressed "to the school children of the United States" a message on the significance of Arbor Day, which, during the month of April, is celebrated in many of the States. The message was as follows:

"To the School Children of the United States—Arbor day (which means simply 'tree day') is now observed in every State in our Union—and mainly in the schools. At various times from January to December, but chiefly in the month of April, you give a day or part of a day to special exercises, and perhaps to actual treeplanting, in recognition of the importance of trees to us as a nation, and of what they yield in adornment, comfort and useful products to the communities in which you live.

"It is well that you should celebrate your Arbor day thoughtfully, for within your lifetime the Nation's need of trees will become serious. We of an older generation can get along with what we have, though with growing hardships; but in your full manhood and womanhood you will want what nature once so bountifully supplied and man so thoughtlessly destroyed; and because of that want you will reproach us, not for what we have used, but for what we have wasted.

THE ROAD TO SUCCESS.

"For the Nation, as for the man or woman and the boy or girl, the road to success is the right use of what we have and the improvement of present opportunity. If you neglect to prepare yourselves now for the duties and responsibilities which will fall upon you later—if you do not learn the things which you will need to know when your school days are over, you will suffer the consequences. So any nation which in its youth lives only for the day, reaps without sowing and consumes without husbanding must expect the penalty of the prodigal, whose labor could with difficulty find him the bare means of life.

"A people without children would face a hopeless future; a country without trees is almost as hopeless; forests which are so used that they can not renew themselves will soon vanish, and with them all their benefits. A true forest is not merely a storehouse full of wood, but, as it were, a factory of food, and at the same time a reservoir of water. When you help to preserve our forests or to plant new ones you are acting the part of good citizens. The value of forestry deserves, therefore, to be taught in the schools, which aim to make good citizens of you. If your Arbor day exercises help you to realize what benefits each one of you receives from the forests, and how by your assistance these benefits may continue, they will serve a good end.

"THEODORE ROOSEVELT."

The Real Meaning of Arbor Day

Arbor Day, as inaugurated at the instance of J. Sterling Morton by a body of practical Nebraska farmers who sorely felt the need of windbreaks and woodlot products, was essentially a day for forest planting. The resolution adopted provided that April 10, 1872, be "especially set apart and consecrated for tree planting in the State of Nebraska, and the State Board of Agriculture hereby name it Arbor Day and urge upon the people of the State the importance of tree planting." On the first Arbor Day a million trees were planted in Nebraska alone. April 10 of this year is the thirty-fifth anniversary of that day, but the changes during this period have only intensified the need for the work which Arbor Day was designed to encourage—planting forests and managing them sensibly. The growing excess of demand over supply caused a great rise in price of timber, not only in the prairie country, where Arbor Day had its birth, but also in the once heavily timbered regions by which the lumber for the building of the nation was so freely furnished. Even some of the very States in which timber was burned to clear farms can not now furnish sufficient lumber needed for its own needs, nor even the ties for the railroads that cross them.

How important the vast wealth of the forest has been in the development of this country is strikingly shown by a rough estimate of the value of the lumber products of six leading States, even at the low prices that until recently obtained. The figures are averages of the 10-year census returns.

Value of forest products of six leading States, 1850 to 1906:

States.	1850–1860	1860–1870	1870–1880	1880–1890
Michigan	$18,838,665	$196,249,000	$421,981,620	$677,859,480
Wisconsin	29,174,730	98,735,745	165,415,330	394,593,955
Pennsylvania	93,615,590	199,665,225	256,981,720	257,726,645
New York	118,621,770	159,179,115	177,975,690	191,995,875
Minnesota	6,577,015	27,783,825	58,326,000	162,205,850
Maine	65,201,665	92,817,535	96,648,075	98,917,610

States.	1890–1900	1900–1906	Total.
Michigan	$687,062,445	$284,579,565	$2,316,570,775
Wisconsin	593,006,300	306,091,746	1,587,017,806
Pennsylvania	524,189,675	202,177,065	1,334,355,920
New York	164,637,620	87,202,170	899,610,240
Minnesota	343,301,465	230,305,410	828,499,565
Maine	126,695,275	94,281,252	574,561,412

And no stronger argument for the protective value of forests is needed than the recent floods in the Ohio Valley, which brought loss of life and of property valued at millions, because mountains and hills had been bared of forest by excessive cutting, followed by fires.

The forest problem, then, is one that affects not only the nation, but the State, the community, and the individual. And on Arbor Day and in the Arbor Day season great profit may be had, both through planting trees for use or beauty and through seeking to gain a closer touch with the forest. The lifelong study and experience of trained men have made it possible for us to learn about the characteristics of trees and to manage forests accordingly; have shown us how different trees make different demands upon light, soil, and moisture; how trees growing in the forest help and hinder each other; what woods are the most useful, and the extent to which new uses may be found for trees hitherto undervalued.

Since the great resources of nature are entrusted to our keeping like the talents of the parable, and we must render an account of them to posterity, men are in duty bound to husband and improve them as well as to enjoy them. Again, in the present age of endless activity there is felt increasingly the need of proper rest and refreshment, for recreation in the true sense of renewing our powers, and this is one of the great uses of the forest—to supply health and vigor for those who are in need of going back to nature. The preservation of the forest thus becomes a matter affecting character and happiness in many ways, not only in the present generation, but even more so in the generation to come. This thought is full of suggestion for the churches, many of which are already taking up the subject either through the pulpit or through the men's clubs which are now so important a part of their social life.

Many of the States issue Arbor Day annuals, some of which, in their descriptions and illustrations of native trees and in the information they furnish concerning their planting, protection and use, form valuable contributions to forestry. An Arbor Day annual which especially carried out the intent of the authors of Arbor Day, was issued in 1902 by Arthur LeFevre, then State Superintendent of Public Instruction in Texas. This took account of the forest resources of Texas, and of the organizations for forest work in the states, in the nation, and in foreign nations; and discussed the practical value of woodlots and of forests as a protection to many industries.

In Hawaii Arbor Day was first observed on November 3, 1905,

when the Governor generously contributed half of a fund for a prize of $5 for each of the 154 public schools, to be given to the grade whose planting on Arbor Day secured most successful results. The other half of the fund was raised by subscription. Most of the trees were furnished by the State nursery at Honolulu. The Pennsylvania Forestry Association also offered prizes last spring—four of $15 and four of $10—for the best examples of commercial, park, and roadside planting, judged on the date of the autumn Arbor Day. This plan should have a twofold value; first, in stimulating forest planting, and second, in giving publicity to plantations which exhibited exceptional judgment, good taste and energy.

Arbor Day is pre-eminently a school celebration. Very much has been done in beautifying school grounds through observance of the day, and very much more will be accomplished as the educational features of the occasion develop broadly. The possibilities of Arbor Day celebration in the public schools seem almost infinite, when careful consideration is given the work of one county—Winnebago County, Illinois. There the heartiest encouragement of Arbor Day principles is given in the county institute and in personal visits to the schools, the county superintendent, Mr. O. J. Kern, having fully grasped the broader significance of Arbor Day work. An annual is published, illustrated with photographs of school grounds and of lawns adorned by rows and clumps of planted trees, giving planting suggestive plans, with diagrams. Workshops are shown, of the larger schools, where in practical manual training boys are constructing guards for the young trees to be planted on Arbor Day. Best of all, near-by views are given of the true forest where possible, of which the Forester, Mr. Pinchot, has said, "Perhaps no other natural agent has done so much for the human race, and has been so recklessly used and so little understood."

Arbor Day Tree Planting

Tree planting on Arbor Day by the schools is usually accompanied by literary exercises consisting of essays, songs, recitations and addresses. In most cases the literary program forms the absorbing feature of a day intended for another purpose. I am not attempting to discourage the literary exercises in connection with the tree planting program, as it is a means of stimulating interest and bringing together the community and causing a revival of interest in both school and trees, but I suggest that much more attention be given to the matter of arborculture features. The selection, the method of planting, the time when to do it and the care devoted to the trees after the Arbor Day program has been rendered, are the vital elements which bring results from the exercises, and if these matters are not given emphasis the day's program falls far short of the purpose.

The selection of the trees for Arbor Day planting should be attended to with care, and only such ones chosen and planted as are hardy to the conditions at hand. The school ground should not be made a place of experiment, and, naturally, trees on public grounds are exposed to injury more than on private grounds. Any trees which can not endure moderate abuse should not be chosen, as under the best restrictions the soil will be trampled, twigs broken and other numerous common injuries imposed. The soil of the school grounds or other grounds intended for planting should be studied, because differences in soil make necessary differences of tree selection and all the attendant features of propagation. Because a tree is known to grow in the locality does not imply that it will grow on any spot in the community. Sandy soils and clay soils are found in alternate relation in almost any part of the State, in both strata and territorial connections, and a tree which thrives in one soil may have a struggle to exist in the other. When a study of the soils has been made to determine the differences in kind and porousness and then adaptable trees selected, rightly planted and properly cared for, after success is almost assured.

There are also other questions which should be considered before the selection of trees is made, and they are the permanent de-

votion of the ground to the purpose for which tree planting is done, the immediate needs and the space allotted to a tree. If the grounds under consideration are to be devoted permanently, so far as can be foretold, to the use for which it is set apart and the present needs of tree decoration are not urgent, then the long-lived trees should be chosen and such as will correspond with the other conditions of soil and moisture. If the area is not likely to be permanently devoted to the present uses and the decoration is to fill a limited time and necessary want, then the short-lived, fast growing trees should be selected. In places where the conditions are permanent and the needs immediate, a compromise can be made by planting the different lived trees in alternate harmony. They may be planted closely and at a proper development in growth the short-lived trees can be cut out and the permanent trees left at proper distances.

In places where the space will not permit large spreading topped trees the selection should be of trees, the tops of which are more dense and compact. The following lists will give information concerning selections. The long-lived trees best suited for decorative plantings on permanent grounds are the American elm, American ash, sugar maple, Norway maple, tulip poplar, linden or basswood, American chestnut, sweet gum, sycamore, scarlet oak, red oak, white oak, yellow locust and some of the evergreens. Those best suited for limited time are red maple, ginkgo, pin oak, horse chestnut, hackberry, catalpa, Lombardy poplar, some of the evergreens and a few foreign varieties. Where the space is limited but permanent the trees best suited and which adapt themselves to the conditions are the sugar maple, Norway maple, linden, chestnut, sweet gum, American ash, scarlet and red oak and tulip poplar. The trees which should not be planted any place for decoration are the Carolina poplar, silver maple and other similar kinds.

The time and method of planting should be given the closest attention. The time is subject to difference of opinion, but such is mostly due to the object in mind. If an agent or individual cares only to dispose of his trees he may argue that any time is good for planting, but a scrupulously honest individual will not disregard the proper time to plant. In Indiana fall planting may sometimes be done to advantage, but it can not be held as a rule to practice. In all ordinary conditions early spring planting is more successful, especially for deciduous trees. The best time is immediately after the freezing is over and the soil is dry enough. The reasons given against fall planting are that the trees do not get a

sufficiently established root system to sustain them against the hard freezings and thawings of the winter. If it is possible the planting should be done on a cloudy, cool day, and unless the atmosphere is very moist, the trees should be kept moist by having their roots submerged in water or a thin mixture of earth and water and only removed as they are planted. A very few minutes' exposure to the air will injure the small fibrous roots which are the feeders of the tree.

The holes for the tree should be dug a few days before the time of planting. They must be large enough so that the roots can be placed in their natural positions without cramping. It is well to have a foot or more additional space on all sides of such ample depth that plenty of loose soil can be placed under the roots. In digging the holes place the top soil by itself and if the lower soil is poor and lumpy, it should be substituted by richer finely pulverized earth for the planting. Use no manure unless it is thoroughly mixed with earth, and such should not be placed around the roots, as manure will burn and rot them. Good, clear, rich, heavy, finely pulverized soil is at all times better for tree planting. By digging the holes a few days beforehand the soil requisites can be arranged and the proper moisture conditions secured. If the earth is too wet it will afford time for proper drying out, and if too dry it will afford time to fill the holes with water and saturate till the result is satisfactory for good planting. A good drainage is essential, as but few trees will live in a place where water settles around the roots and is retained by a heavy clay.

The tree should be set at a depth of an inch deeper than it originally grew, and should be set firmly and fastened by strings tied to stakes to prevent the winds swaying and loosening it in the ground. Be careful in doing this not to injure the bark. After planting, the ground should be mulched around with rotten substance either of straw, tanbark or sawdust. This device will not only retain the moisture, but will keep down the weeds and fertilize the soil. With this treatment watering will not be necessary except in excessive drought, in which case several gallons of water should be poured around the roots of the tree every few days until the danger is passed.

Many of the reasons for the failure of the tree to live and grow after it has been planted can be ascribed to the injuries sustained in digging it up. The roots are torn, strained or mutilated or such scanty root system is taken up that the tree has no means of keeping up life. In digging up the tree the roots should be pre-

served as entire as possible and entirely practical. If the tree is of a dimension of an inch or two in diameter and of four or five years' growth, the root system should be preserved for at least three feet around the stem. Extreme caution should be exercised in retaining the small feeders. If a large tree is taken up a ball of earth of the dimensions above should be kept compactly intact with it and planted. Having carefully dug up the trees, the roots should be examined and cut away smoothly and completely all bruised and broken roots. By so doing decay will not occur and fibrous roots will form quickly around all such places. Top roots may be cut down to easy requirements for planting in the cavities. The tops of the trees should always be pruned back to harmonize with the diminished root system caused by digging. A good suggestion is the cutting of the branches back from one-third to one-half, but at no instance should they be cut to bare poles. In cutting the top back the branches should always be cut near a bud, as the pruned member will always die back to the nearest bud. This will avoid the dead stubs so frequently seen on pruned trees a year or so after.

When trees are selected from the forest, they should be secured from regions open to the sun rather than from a densely shaded area, as trees from the latter places are tender and weak and will not survive the sun and open exposure. All newly planted trees should be protected on the extreme side to the sun exposure by boards or tree boxes. They should also be protected from stock and other dangers by tree boxes.

SEEDLING TRANSPLANTING.

The preparation of the soil for planting seedlings is the same in all instances as has been given for seed planting. The making of excavations to receive the trees is the thing most difficult, to not impede rapid progress. If the trees are large and have spreading roots, the places must be made large enough to receive the roots without cramping them. It is better, therefore, to transplant the seedlings at an early age, in order to lessen the work as well as to insure better results of growing. Most seedlings at the ages of one and two years do not possess much root system, simply a straight stem with small hair fibres. If the ground is well prepared the planter can make the holes with a sharpened handspike by jabbing it into the loose soil and prying in all directions. If it cannot be performed in this manner a circular spade, dibble or other implement adaptable to make the small holes necessary can be used. If the former plan is followed the planter can quickly make the holes,

insert the slender root and firmly press the dirt around it. In all instances the dirt should be pressed thoroughly around the roots, so that no air remains around them. To this cause may be attributed the death of many trees planted. In some instances a spade was inserted into the soil and the earth pried apart, the tree root inserted, the spade removed and the earth stamped firmly upon the roots. For planting the small seedlings various methods may be employed to make the excavations successfully.

If larger trees are planted, more work and effort will be required to make the holes and to plant the tree properly.

The digging of the seedlings should be performed in a way not to injure them. In a small nursery, and when the trees are young, a sharp spade can be used by cutting along both sides of the rows and then lifting the trees out carefully. At all times mangling the trees should be avoided. It is not essential to prune unless the trees should become broken, when they should be pruned smoothly.

The trees may be dug in the fall and heeled over winter for early planting in the spring. Young trees in this climate should not be planted in the fall. The winters are too severe on them in their newly planted condition. The same thing is also true, in my judgment, for larger trees.

The trees can be heeled in the cellar by keeping moistened dirt over the roots. The usual method of heeling trees is to dig a trench deep enough to bury the roots and the greater part of the bodies of the trees. Extend the trench east and west, the south bank sloping at an angle of about thirty degrees. Place the trees in the trench in single layers with the tops to the south and cover each layer with fresh earth. It is advisable to leave only the branches exposed. They may be left in the trench till they are taken out for planting. Select the site for the trench where the drainage is good.

When removed for planting, the roots should be plunged into a vessel containing a mixture of clay and water formed into a slush. The same thing should be done to the seedlings when taken from the nursery, unless they are immediately planted or heeled in. The roots of any tree which it is intended to transplant should never be allowed to become dry.

The distances at which trees should be planted are 4, 5 and 6 feet apart for regular forest plantings, and should be in rows both ways to admit of cross-cultivation. They should be plowed or cultivated in some manner to keep down the weeds till they are large enough to survive by themselves.

The close planting enables them to soon shade the ground and

thus conserve the moisture to them. Besides, it aids in natural trimming and long, straight trunk formation. Successive trimmings will be necessary when they begin to crowd and smother out.

The principle of tree growth is that if the tree is grown in the open it branches and forms a shade tree. The growth goes to limbs and branches instead of body formation. If it is crowded, it goes up in search of light, does not branch, and consequently a good trunk is formed to make the tree valuable.

MISCELLANEOUS BULLETINS AND CIRCULARS

BY

United States Department of Agriculture,

FOREST SERVICE.

GIFFORD PINCHOT, Forester, AND ASSISTANTS

1907

These bulletins and circulars are selected because of the practical forestry suggestions they contain for work in Indiana, and for the industrial discussion showing the foundation principles of the forestry movement and the economic features embodied as well. Their careful study is requested because of their application to local forestry work.

W. H. FREEMAN.

UNITED STATES DEPARTMENT OF AGRICULTURE,
Division of Entomology—Circular No. 15, Second Series.

General Work Against Insects Which Defoliate Shade Trees in Cities and Towns*

The question of proper work against the insects which affect shade trees in cities and towns naturally divides itself under two heads: (1) What can be efficiently and economically done by city governments? (2) If city or town administrators will not appropriate a small amount of money to carry on work of this kind, what can citizens who are interested in the question of shade trees do?

INTELLIGENT SUPERVISION DESIRABLE.

The planting of shade trees seems to be considered a legitimate function of the board of public works in every municipality. It is sometimes done by a specially appointed officer, under the control of the superintendent of streets and sewers; or it is sometimes placed in charge of a subcommittee of the board; or a special commission of outsiders is appointed to superintend the work. Admitting that the planting of shade trees is a public matter, their care should also be a public duty. Yet in not one of the larger or smaller cities of the Eastern United States with which the writer is familiar is any proper amount of work done by the public authorities against shade-tree insects. New York is the only city in the country where a man of entomological knowledge is employed to direct operations against shade-tree insects, either in the streets or the public parks. That New York's investment is a good one no one who knows the work of Mr. E. B. Southwick can doubt. By this remark the writer does not wish to be understood as advocating the appointment of a paid entomologist under every city government, although where the parks are large in cities situated within the region of greatest shade-tree insect activity, such a course would always be desirable. With an intelligent and industrious superintendent of parks, or a city forester, or whatever he may be termed, and the wise expenditure of a comparatively small amount of money each year, the shade trees of any city could be kept green throughout the summer. The amount of money to be

*In advance, from an article entitled "The Shade-tree Insect Problem in the Eastern United States," to be published in the Yearbook of the Department for 1895.

expended in this direction would naturally vary with the number of trees to be attended to, as well as with the variety and the size of the trees and the geographical location of the city. Even in Brooklyn, however (and this seems to the casual observer to be the most unfortunate of all our Eastern cities from this standpoint), it is within bounds to estimate that the expenditure of $3,000 to $4,000 a year would result in green shade trees the summer through. This amount, however, will in all probability not need to be an annual appropriation. The first cost of a proper spraying apparatus will have to be added, but the apparatus once purchased and thorough work performed for two or three years, consecutively, the probabilities are strong that the number of shade-tree insects will be reduced to such an extent that a much smaller annual expenditure will be sufficient.

KIND OF APPARATUS TO USE.

The question of a proper spraying apparatus is a rather serious one, since in this direction a considerable amount of money should be expended. A steam apparatus will do the work with much greater rapidity than a hand pump, and yet with a strong double-acting force pump, which can be operated by one man, and a tank of 100 gallons capacity mounted on a strong cart, many large trees can be well sprayed in the course of a day. From such a pump two lines of hose may be run with advantage. The working force of such an apparatus should be, a horse to draw the cart, a man to drive and do the pumping, and one man to each of the lines of hose. Several such machines have been used with good results in the work of the Gypsy Moth Commission, both for street trees and in the public parks. A steam apparatus, however, of such a capacity that a pressure of 75 pounds per square inch may be gained, will enable the operation of four or five lines of hose simultaneously. The rapidity of work will therefore be doubled, and certainly by the use of two such pumps the shade trees of any ordinary city can be gone over with sufficient rapidity to destroy all insects within the required time. A boiler mounted on a truck, the boiler to be complete with all fixtures—smokestack, bonnet, firing tools, and springs to the truck—and a pump having a capacity of 10 to 20 gallons a minute, connected up to the boiler ready for operation. can be purchased for a sum well within $500. This truck should be mounted on wheels with broad tires. Connecting this apparatus with a proper tank cart would be an additional expense not to exceed $100 for a tank of a capacity of 200 gallons. Such an ap-

paratus furnished with hose and smooth-bore nozzles of about one-sixteenth inch in diameter, when discharging, under 40 pounds pressure, from each of several such nozzles, would spray about half a gallon of insecticide mixture per nozzle per minute.

A strong steam pump to be used in connection with a small oil-burning boiler, the whole apparatus on a smaller scale than that described above, has been estimated at $275 by a prominent New York firm, delivered on board the cars.

There is no reason why an old steam fire engine could not be readily arranged for this shade-tree spraying work. In one or two instances a steam fire engine has been used for this purpose without modification, the object being simply to knock the insects from the trees by means of a strong stream of water. By such means as this Col. John M. Wilson, U. S. A., now Superintendent of Public Buildings and Grounds in Washington, kept the elms green at West Point several years ago, when he was superintendent of the Military Academy. In every large city where the fire department is necessarily kept in the best condition, an engine is occasionally retired. The transfer of such a retired engine to the street department could no doubt be readily made, and a little work by a competent steam fitter would transform it into a most admirable insecticide machine. In this way the initial expenditure for machinery would be avoided.

WHEN THE WORK SHOULD BE DONE.

When the spraying apparatus has been once provided, the funds necessary for the purchase of insecticides and the necessary labor must be available at the proper time. If the work is not done promptly and at just the right time, more or less damage will result, and a greater expenditure will be necessary. During the latter part of May and the first of June, in the case of nearly all prominent leaf-eating shade-tree insects, one or two thorough sprayings must be made. In fact a second spraying, begun immediately after the completion of the first one, will be in ordinary cases as much as need be expected. In addition to this spraying work, a force of men must be employed for a time in July to destroy the elm leaf-beetle larvæ as they are descending to the ground and to burn the webs of the first generation of the fall webworm. This will finish the summer work. The winter work will consist of the destruction of the eggs of the white-marked tussock moth, the cocoons of the fall webworm, and the bags of the bagworm. The number of men to be employed, and the time occupied, will depend

upon the exigencies of the case. Upon the thoroughness of this work will depend, to a large extent, the necessity for a greater or less amount of the summer work just described.

We have now to consider what can be done by citizens where city governments will not interest themselves in the matter. It is unreasonable to expect that a private individual will invest in a spraying apparatus and spray the large shade trees in front of his grounds, therefore in spraying operations where large trees exist in numbers there must be combination of resources. This affords an opportunity for the newly invented business of spraying at so much per tree. In Bridgeport, Conn., Mr. W. S. Bullard, who was formerly and is yet for the greater part of the year a roofer and paver, has constructed several cart sprayers, and during the months of June and July (at a time, by the way, when the men in his employ are apt to be out of work) he sprays trees on the grounds of private individuals and along the street in front of their grounds, under contract, at so much per tree, guaranteeing to keep the trees in fair condition during the season. His work has been directed solely against the elm leaf-beetle, since that is the only insect of great importance in Bridgeport. In the month of July last the writer, in driving through the streets of Bridgeport, found it easy to pick out the trees which had been placed in Mr. Bullard's care. Such elms were green, while all others were brown and nearly leafless. The defect of this plan as a general practice lies in the fact that not all property owners or residents can afford to employ a tree sprayer, while others are unwilling, since they deem it the business of the city authorities or do not appreciate the value of tree shade.

CO-OPERATIVE EFFORT.

Any effort, therefore, looking toward the arousing of popular sentiment or the banding together of the citizens in the interest of good shade is desirable. A most excellent plan was urged by one of the Washington newspapers the past summer. It advocated a tree protection league and each issue of the paper through the summer months contained a coupon which recited briefly the desirability of protecting shade trees against the ravages of insects, and enrolled the signer as a member of the league pledging him to do his best to destroy the injurious insects upon the city shade trees immediately adjoining his residence. This was only one of several ways which might be devised to arouse general interest. The average city householder seldom has more than half a dozen street

shade trees in front of his grounds, and it would be a matter of comparatively little expense and trouble for any family to keep these trees in fair condition. It needs only a little intelligent work at the proper time. It means the burning of the webs of the fall webworm in May and June; it means the destruction of the larvæ of the elm leaf-beetle about the bases of the elm trees in late June and July; it means the picking off and destruction of the eggs of the tussock moth and the bags of the bagworm in winter, and equally simple operations for other insects, should they become especially injurious. What a man will do for the shade and ornamental trees in his own garden he should be willing to do for the shade trees 10 feet in front of his fence.

L. O. HOWARD,
Entomologist.

Approved: CHAS. W. DABNEY, JR.,
Assistant Secretary.

Washington, D. C., March 6, 1896.

U. S. DEPARTMENT OF AGRICULTURE.
Forest Service—Circular 97.
GIFFORD PINCHOT, FORESTER.

The Timber Supply of the United States

BY R. S. KELLOGG,
Forest Inspector.

FOREST PRODUCTS.

The lavish manner in which the United States has consumed the products of its forests and the rapidity with which our timber supply is melting away are wholly unappreciated by those who have never given the matter more than passing consideration. Familiar as all are with the use of wood for every purpose and in every industry, it is only when the various items are added that there begins to come a realization of the indispensable place the forests fill in the national economy. A conservative statement of the present yearly output of the forests is shown below, the values given being those at the point of production:

TABLE 1.—*Annual output of forest products.*

	Quantity.	Value.
Lumber ... board feet	35,000,000,000	$560,000,000
Firewood ... cords	100,000,000	350,000,000
Shingles and lath		30,000,000
Hewed cross ties	70,000,000	30,000,000
Cooperage stock		25,000,000
Turpentine and rosin		25,000,000
Pulp wood ... cords	3,000,000	15,000,000
Timber exported (unsawed)		10,000,000
Mine timber, posts, poles, and other products		30,000,000
Total		$1,075,000,000

The total quantity of wood cut to obtain the products listed in the table was not less than 20 billion cubic feet.

Rapidly as the population of the United States has increased, the lumber consumption has increased still more rapidly. In round numbers, and allowing for incomplete reports, the lumber cut in 1880 was 18 billion feet; in 1890, 24 billion feet, and in 1900, 35 billion feet. The increase in population from 1880 to 1900 was 52 per cent., but in lumber cut 94 per cent. The United States is now using annually 400 board feet of lumber per capita, while the average for Europe is but 60 feet per capita.

Table 2 affords a better understanding of the vast amount of

lumber used. This gives the lumber cut of the principal States since 1880. The figures for 1880, 1890, 1900, and 1905 are those compiled by the census; the total cut is estimated by assuming an average cut between census dates. This brings the total cut since 1880 to more than 700 billion feet—a truly astonishing figure when we stop to consider it. This quantity of lumber would make a floor 1 inch thick over Vermont, Massachusetts, Connecticut, Rhode Island, and Delaware, or an area of 25,000 square miles.

TABLE 2.—*Lumber cut of the United States, 1880–1906.*

State.	Reported by census of—				Estimated total cut, 1880–1906.	Per cent.
	1880.	1890.	1900.	1905.		
	M board feet.	*M board feet.*	*M board feet.*	*M board feet.*	*M board feet.*	
Alabama	251,851	586,143	1,096,539	1,243,988	19,625,000	2.8
Arkansas	172,503	526,091	1,595,933	1,680,536	23,932,000	3.4
California	304,795	515,823	734,232	1,077,499	15,789,000	2.2
Colorado	63,792	79,906	133,746	141,914	2,614,000	.4
Connecticut	64,427	48,277	107,594	69,376	1,874,000	.3
Florida	247,627	411,436	788,905	812,693	14,802,000	2.0
Georgia	451,788	572,970	1,308,610	1,135,910	21,865,000	3.1
Idaho	18,204	27,800	65,331	211,447	1,526,000	.2
Illinois	334,244	218,938	381,584	211,545	7,548,000	1.1
Indiana	915,943	707,115	977,878	563,853	21,165,000	3.0
Iowa	412,578	568,816	351,769	281,521	11,410,000	1.6
Kentucky	305,684	420,820	765,343	586,371	13,618,000	1.9
Louisiana	133,472	303,591	1,113,423	2,459,327	19,989,000	2.8
Maine	566,656	564,243	756,515	863,860	17,119,000	2.4
Maryland	123,336	81,078	183,393	166,469	3,394,000	.5
Massachusetts	205,244	208,655	342,058	262,467	6,637,000	.9
Michigan	4,172,572	4,245,717	3,012,057	2,006,670	93,436,000	13.2
Minnesota	563,974	1,079,403	2,341,619	1,942,248	38,174,000	5.4
Mississippi	168,747	452,797	1,202,334	1,727,391	20,173,000	2.9
Missouri	399,744	395,755	715,968	553,940	13,346,000	1.9
Montana	21,420	89,511	255,685	236,430	3,757,000	.5
New Hampshire	292,267	266,890	562,258	491,591	10,103,000	1.4
New Jersey	109,679	32,285	72,660	44,058	1,585,000	.2
New York	1,184,220	909,990	874,754	581,976	23,765,000	3.4
North Carolina	241,822	509,436	1,278,399	1,318,411	20,486,000	2.9
Ohio	910,832	541,076	957,239	420,905	18,886,000	2.7
Oregon	177,171	444,565	734,181	987,107	14,166,000	2.0
Pennsylvania	1,733,844	2,113,267	2,321,284	1,738,972	53,589,000	7.6
South Carolina	185,772	197,940	466,109	609,769	8,466,000	1.2
Tennessee	302,673	450,097	939,463	775,885	15,858,000	2.3
Texas	328,968	839,724	1,230,904	1,406,473	24,109,000	3.4
Vermont	322,942	370,155	365,869	337,238	9,255,000	1.3
Virginia	315,939	409,804	956,169	949,797	16,176,000	2.3
Washington	160,176	1,061,560	1,428,205	2,485,628	30,299,000	4.3
West Virginia	180,112	299,709	773,583	855,889	12,654,000	1.8
Wisconsin	1,542,021	2,817,200	3,361,943	2,623,157	70,647,000	10.0
All others	200,317	126,270	226,977	264,854	4,875,000	.7
Total	18,087,356	23,494,853	34,780,513	34,127,165	706,712,000	100.0

There are some striking things shown in this table. Since 1880 Michigan has produced over 93 billion feet of lumber, or 13.2 per cent. of the output of the entire United States; Wisconsin, 70 billion feet, or 10 per cent. of the total; Pennsylvania, 53 billion, or 7.6 per cent., and Minnesota, 38 billion, or 5.4 per cent. The combined output of these four States since 1880 is almost 256 billion feet, or 36 per cent. of the total production of the United States.

No less striking than the increase in output has been the shifting of the sources of supply, as one region has been cut out and another invaded. The percentage of the total lumber cut furnished by the principal regions since 1850, according to census figures, is as follows:

TABLE 3.—*Geographical distribution of total lumber product.*

Year.	North-eastern States.	Lake States.	Southern States.	Pacific States.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1850	54.5	6.4	13.8	3.9
1860	36.2	13.6	16.5	6.2
1870	36.8	24.4	9.4	3.8
1880	24.8	33.4	11.9	3.5
1890	18.4	36.3	15.9	7.3
1900	16.0	27.4	25.2	9.6

The Northeastern States reached their relative maximum in 1870 and the Lake States in 1890. The Southern States are undoubtedly near their maximum today, with about 35 per cent. of the total lumber product, and the time of ascendancy of the Pacific States is rapidly approaching. Since the census of 1900 the product of the Pacific States has risen from less than 10 per cent. of the lumber output of the country to 20 per cent. There will be no more shifting after the Pacific States take first place, since there is no new region of virgin timber to turn to.

The shifting of the chief sources of supply has, of course, been accompanied by a change in the kinds of lumber produced. There was a time when white pine alone constituted one-half of the total quantity. In 1900 this species furnished but 21.5 per cent., and in 1904 only 15 per cent. of the lumber cut. On the other hand, Douglas fir is credited with 5 per cent. in 1900 and 13 per cent. in 1905.

FOREST RESOURCES.

The great demand made upon the forests naturally leads to the question: How much timber is now standing in the United States and how long will it last at the present rate of cutting?

The general distribution and character of the original forests of the United States are shown by fig. 1. A glance at this discloses that five groups of States embrace the naturally timbered areas of the country—the Northeastern States, the Southern States, the Lake States, the Rocky Mountain States, and the Pacific States. Of these, the two groups last mentioned are occupied by forests in which practically all the timber-producing trees are coniferous,

the first three by both conifers and hardwoods. The earliest attack was upon the white pine of the Northeast, the original stand of which is almost entirely cut out. The present stand in the Northeastern States is mainly spruce, second-growth white pine, hemlock and hardwoods.

The Southern States produce essentially four types of forest, which may broadly be said to divide the land among them according to elevation above sea level. The swamp forests of the Atlantic and Gulf coasts and the bottom lands of the rivers furnish cypress and hardwoods. The remainder of the coastal plain from Virginia to Texas was originally covered with "southern" or "yellow" pine —the trade name under which the lumber of several pines is now marketed. The plateau which encircles the Appalachian range and the lower parts of the mountain region itself support a pure hardwood forest, while the higher ridges are occupied by conifers—mainly spruce, white pine, and hemlock.

The Lake States still contain much hardwood forest in their southern portions. In the north the coniferous forest includes, besides the rapidly dwindling pine, considerable tamarack, cedar, and hemlock.

The chief timber trees of the Rocky Mountain forest are western yellow and lodgepole pine, while the Pacific forest is rich in the possession of half a dozen leading species—Douglas fir, western hemlock, sugar and western yellow pine, redwood, and cedar.

When an attempt is made to estimate the amount of timber of these various species and regions, the deficiency of our knowledge becomes plain. Various estimates of the stumpage have been made, it is true, but it must be said at the outset that no authoritative estimate can be made at the present time, since the magnitude of the task and the many difficulties involved have hitherto prevented the gathering of the necessary data. Nevertheless, certain general conclusions can be established. In the interest both of the lumber trade and of the public an exact knowledge of the situation which confronts the country is called for, since the lack of such knowledge creates uncertain business conditions and prevents the framing of a rational and comprehensive plan for the best use of our forest resources.

The principal estimates of the stumpage of the United States which have been made since 1880 are given in Table 4. The first is that presented by Sargent in Volume IX of the Tenth Census. This estimate, in addition to being too low for almost every species considered, with the possible exception of the hardwoods, is notable

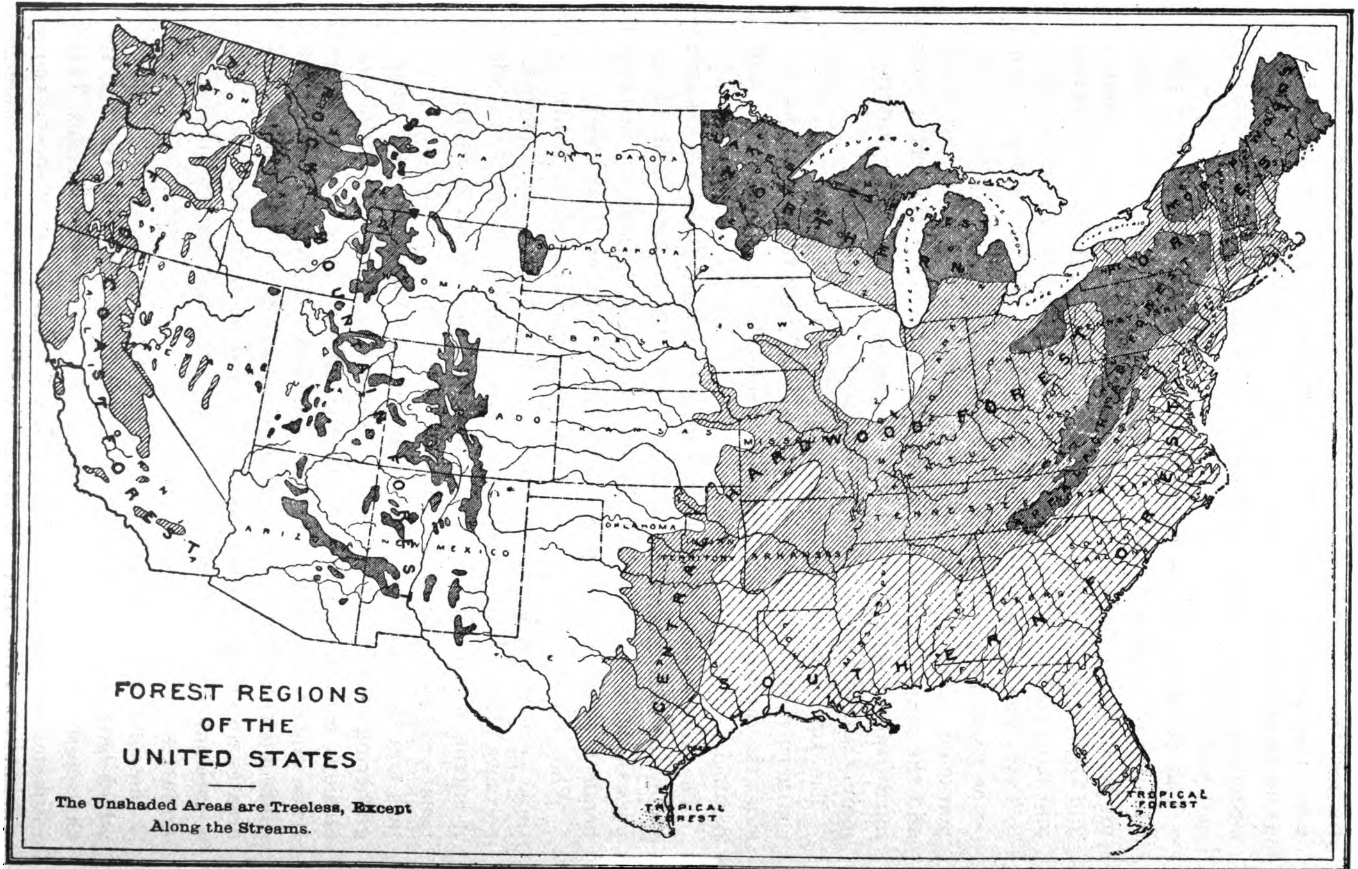


FIG. 1.—Map showing forest regions of the United States.

for its omission of the timber which exists today in greater quantity than any other—Douglas fir—and also for the omission of western yellow pine, another important species. The next estimate is that of Hotchkiss, published in his "Lumber and Forest History of the Northwest" in 1898. He does not go into details, but simply estimates that the total stumpage is 1,400 billion feet, of which the Northern States have 100 billion, the Southern States 300 billion. and the Pacific States 1,000 billion feet. Next are the estimates prepared by Gannett and published by the Twelfth Census in Bulletin 203. These are the most carefully prepared estimates yet made and have been widely quoted. In addition to bringing the figures for several species up more nearly to the probable stand, these estimates also cover Douglas fir, western yellow pine, and sugar pine, which were omitted in the census of 1880. The next estimate is the one made by Fernow in 1902 and published in his "Economics of Forestry." Like that of Hotchkiss, this is also a regional estimate, the stumpage of the Northern States being placed at 500 billion feet, that of the Southern States at 700 billion, and that of the Western States at 800 billion, a total of 2,000 billion feet and the highest of any given in the table. It may be noted in passing that in a previous estimate published in 1896, in Circular No. 11 of the Division of Forestry, Fernow placed the total stumpage of the country at 2,300 billion feet, which, upon further consideration,

TABLE 4.—*Estimate of stumpage of the United States.*

Kind of timber.	Census, 1880.	Hotchkiss, 1898.	Census, 1900.	Fernow, 1902.	Long, 1903.	American Lumberman, 1905.
	M board feet.	*M board feet.*	*M board feet.*	*M board feet.*	*M board feet.*	*M board feet.*
White pine	87,755,000		50,000,000		60,000,000	
Eastern and northern pine						55,000,000
Southern yellow pine	237,141,500		300,000,000		187,250,000	300,000,000
Eastern spruce	12,265,000		50,000,000		18,221,000	75,000,000
Eastern hemlock	20,165,000		100,000,000		56,571,000	100,000,000
Douglas fir			300,000,000		260,000,000	350,000,000
Western yellow pine			125,000,000		138,000,000	250,000,000
Cypress	a2,153,600		65,000,000			65,000,000
Redwood	25,825,000		75,000,000		75,000,000	75,000,000
Cedar	22,800,000				27,640,000	
Sugar pine			25,000,000			50,000,000
Other conifers	12,500,000					250,000,000
Total conifers	420,605,100		1,090,000,000		822,682,000	1,570,000,000
Total hardw'ds	435,685,000		300,000,000			400,000,000
Region:						
North'n States		100,000,000		500,000,000		
South'n States		300,000,000		700,000,000		
West'n States				800,000,000		
Pacific States		1,000,000,000				
Total	856,290,100	1,400,000,000	1,390,000,000	2,000,000,000	822,682,000	1,970,000,000

aFlorida and Alabama only.

he evidently considered too high. At the thirteenth annual meeting of the Southern Lumber Manufacturers' Association, in New Orleans, January, 1903, R. A. Long read a paper upon "Stumpage," in which the figures given in the fifth column of Table 4 were presented. Long's estimate does not cover cypress, sugar pine, or hardwoods. Its principal point of interest is that it differs so radically—about 38 per cent.—from that of the census of 1900 upon the stumpage of southern yellow pine. The last estimate given in the table is that published in the American Lumberman September 23, 1905. It is based primarily upon census data, with the addition of some species and with increased figures for others.

The totals given by the American Lumberman and Fernow are nearly identical; those of Hotchkiss and the census of 1900 differ by 10 million only, and the totals of Long and the census of 1880 would be close together were the omissions in each supplied. It should be remembered, however, in comparing the estimates of 1880 with recent ones that the total cut since 1880 has been over 700 billion feet, of which at least 500 billion feet have been conifers, or 80 billion feet more than the total coniferous stumpage covered by the census of 1880.

The Pacific Lumber Trade Journal, in the issue of January, 1907, gave the following estimate of the stumpage of the Pacific coast, including Idaho, Montana, and British Columbia:

TABLE 5.—*Estimated stumpage of California, Oregon, Washington, Idaho, Montana and British Columbia.*

Kind of timber.	M board feet.	Kind of timber.	M board feet.
Douglas fir	374,064,102	Spruce	25,419,215
Western and yellow pine	175,586,520	Larch	5,078,601
Red cedar	78,961,383	Miscellaneous and hardwoods	5,700,000
Redwood	75,000,000		
Hemlock	60,848,259	Total	850,658,080
Sugar pine	50,000,000		

This total is credited by States as follows:

	M board feet.
Oregon	225,000,000
Washington	195,658,080
California	180,000,000
British Columbia	150,000,000
Idaho and Montana	100,000,000

KINDS OF TIMBER.

White pine.—The original stand of white pine (including Norway pine) in the Lake States has been estimated at 350 billion feet, and this does not seem excessive when everything is considered. The total cut of pine in the Lake States since lumbering began there some seventy years ago has probably been not less than 250 billion feet, and there have also been huge losses by fire. The census estimate of the stand of white pine in 1880 was less than 88 billion feet; yet, according to the annual reports of the American Lumberman, the cut since that date has exceeded 170 billion, and the amount yet remaining was placed at 50 billion by the census in 1900 and at 60 billion feet by Long in 1903. The estimate in 1880 for Minnesota was especially low—only 8,170 million feet. More than four times that quantity has since been taken out, and Minnesota is today furnishing over one-third of the white-pine cut of the United States.

Despite these cheerful statements, however, it is well known that the days of white pine are rapidly passing, and even accepting the most sanguine estimates of the present stumpage it will in a few years cease to be a large factor in the timber supply of the United States. The present annual cut is about 3 billion feet in the Lake States and 1 billion in other States. The total is less than half the cut in the Lake States alone in the latter eighties. At the annual meeting of the Northern Pine Manufacturers' Association in Minneapolis, Minn., January 22, 1907, Secretary J. E. Rhodes made this striking statement:

> Since 1895, 248 firms, representing an aggregate annual output of pine lumber of 4¼ billion feet, have retired from business, due to the exhaustion of their timber supply. Plants representing approximately 500 million feet capacity which sawed in 1906 will not be operated in 1907.

Southern yellow pine.—The census of 1880 estimated the stumpage of southern yellow pine at slightly more than 237 billion feet. The cut from 1880 to 1900 must have been in the neighborhood of 100 billion, and the estimate by the census at the latter date was 300 billion feet. Long disagreed with this, however, and estimated the stand at 187 billion, in 1903, while the Pacific Lumber Trade Journal in January, 1907, placed the present stumpage, in the opinion of the "best-known timber authorities," at 137 billion feet. This would unquestionably be the case were Long's estimate correct, as the cut since 1903 has been at least 40 billion feet. The census estimate of stumpage of yellow pine in the seven most im-

portant States in 1880, Long's in 1903, and the probable cut since 1880 are shown in Table 6. The cut was estimated by assuming the ratio of pine cut to the total lumber cut for each State. The ratio selected is believed to be a conservative one.

TABLE 6.—*Estimated stumpage and cut of yellow pine in seven States.*

State.	Estimated pine stumpage, census 1880.	Estimated pine cut, 1880–1906.	Estimated pine stumpage, Long, 1903.
	M board feet.	*M board feet.*	*M board feet.*
Alabama	21,345,600	17,500,000	11,250,000
Arkansas	41,315,000	15,500,000	10,500,000
Florida	6,615,000	13,200,000	10,500 000
Georgia	16,778,000	20,100,000	12,000,000
Louisiana	48,213,000	16,000,000	45,000,000
Mississippi	24,975,000	17,100,000	46,000,000
Texas	67,508,500	22,900,000	30,000,000
Total	226,750,100	122,300,000	165,250,000

The present annual cut of yellow pine is about 12 billion feet, or a little more than one-third the total cut of all species, and the maximum has probably not been reached. Whether we accept the lowest or the highest estimate of stumpage, it is evident that within ten to fifteen years there will be a most serious shortage of yellow pine.

Spruce.—The stumpage of eastern spruce was estimated at something over 12 billion feet by the census of 1880 and at 50 billion by the census of 1900, the total cut during the period perhaps approximating 30 billion feet. Our ignorance of the actual stand of spruce is further shown by the fact that Long's estimate in 1903 was 18 billion feet, while that of the American Lumberman a year and a half later was 75 billion feet. Maine has always been the great spruce-producing State, and lumbering has gone on steadily there for a longer period than anywhere else in the United States. The spruce stumpage of Maine was placed at 5 billion feet by the census of 1880 and at 21 billion by the State forest commission in 1902. In the meantime probably more than twice the quantity estimated in 1880 had been cut. The present annual cut of spruce in the United States is approximately 1¼ billion feet, of which Maine furnishes about one-third.

Hemlock.—The stumpage of eastern hemlock was estimated at 20 billion feet by the census of 1880 and at 100 billion feet by the census of 1900. The present annual cut is approximately 3 billion feet, of which Pennsylvania, Michigan, and Wisconsin furnish

about three-fourths. The cut of both eastern spruce and eastern hemlock is decreasing, while that of the western spruce and hemlock is increasing.

Douglas fir.—The stumpage of Douglas fir was estimated at 300 billion feet by the census in 1900 and at 350 billion by the American Lumberman in 1905. The Pacific Lumber Trade Journal, in the article previously referred to, estimates the stand of fir in Washington alone at over 119 billion feet. The cut of Douglas fir reported for the census year 1900 was not quite 1¾ billion feet, while the present cut is about 4½ billion feet, with every indication of a rapid increase in the future.

Western yellow pine.—The stand of western yellow pine was estimated at 125 billion feet by the census of 1900, at 138 billion by Long in 1903, and at 250 billion by the American Lumberman in 1905. It is widely scattered and very difficult to estimate. The present annual cut is about 1 billion feet, with two-thirds of the production in the Pacific Coast States.

Redwood.—The redwood stumpage was estimated at less than 26 billion feet by the census of 1880, and at 75 billion by the census of 1900. The annual cut, which is increasing, is now in the neighborhood of 450 million feet.

Cypress.—The stumpage of cypress, for Florida and Alabama only, was estimated at a little over 2 billion feet by the census of 1880. The census of 1900 gave 65 billion feet for all States, as a probable safe figure, and this has been accepted by later estimators. The annual cut is now about three-quarters of a billion feet, with Louisiana supplying approximately 65 per cent. of the total.

Hardwood.—The amount of hardwood stumpage is very indefinitely known, and is determinable only with difficulty, owing to the scattered and uneven stands. It was estimated at some 435 billion feet by the census of 1880, at possibly 300 billion by the census of 1900, and at 400 billion by the American Lumberman in 1905. Whatever the total stumpage may be, that which is fit for the saw is rapidly decreasing. The hardwood cut in 1900 was 8,634,000,000 feet; in 1904, 6,781,000,000 feet. The present annual cut of hardwoods is about 5 billion feet, consisting of approximately 43 per cent. oak, 12 per cent. poplar, 9 per cent. maple, and lesser amounts of numerous other species.

* * * * * * *

Such, in brief, are the leading estimates of our forest resources. Though a hasty glance at Table 4 might make it appear that the supply of timber is actually increasing, since some of the later

estimates are the larger, and in several instances much more timber has been cut from certain regions than was estimated as existing in 1880, this inference would be altogether wrong. Many of the early estimates were based wholly upon inadequate data, and also did not include a great deal of timber that is now considered merchantable. As the timber in any region becomes scarcer the minimum cutting limit is constantly lowered, and timber is taken which was formerly rejected. In New England, for example, 6 inches is now a common cutting diameter for white pine, while in some localities on the Pacific coast nothing below 18 inches is cut.

No one who is at all familiar with the situation doubts for an instant that we are rapidly using up our *forest capital.* In fact, it is unquestionably safe to say that our present annual consumption of wood in all forms is *from three to four times as great as the annual increment of our forests.* Even by accepting the highest estimate of the amount of timber standing we postpone for only a few years the time when there must be a great curtailment in the use of wood if the present methods of forest exploitation are continued. Every indication points to the fact that under present conditions the maximum annual yield of forest products for the country as a whole has been reached, and that in a comparatively short time there will be a marked decrease in the total output, as there is now in several items. Neither is there any great supply of timber to turn to outside of the United States. With the exception of importations of small quantities of high-class woods like mahogany, the only promising source is Canada; but most of the timber there will be required at home. Even now Douglas fir is bringing higher prices in Canadian than in American markets. The course of prices of white pine, yellow poplar, and hemlock since 1887 and of yellow pine since 1894 is shown in fig. 2. The quotations are for the first of each year.

FOREST OWNERSHIP.

In view of conditions which undeniably exist it becomes of the utmost importance that vigorous steps be taken to insure a future supply of timber. The most liberal estimate which has been made of the wooded area of the United States—that of the Geological Survey—places it at 700 million acres, while other careful estimators have placed the forest area as low as 500 million acres. Table 7 gives the wooded area of each State according to the Geological Survey, together with the area of National Forests, or Federal forest reserves, that of State forest reserves, and that of the private or unreserved public forests. The latter item was determined by

deducting the area of State or National Forests in each State from the total wooded area, and in consequence of using this method certain sources of error are introduced. The National Forests in Nebraska and Kansas are not wooded areas, but areas which are more suitable for the production of timber than for ordinary agriculture, and they were set aside for the purpose of forest planting. A considerable amount of open land is included within the boundaries of other National Forests; and it is probable that in some States the total wooded area is greater than that estimated by the Geological Survey. Thus, while no figures are given for the private and unreserved public forests in Utah and Wyoming there is quite an area of such forests in these States, and more than is indicated in a number of other States.

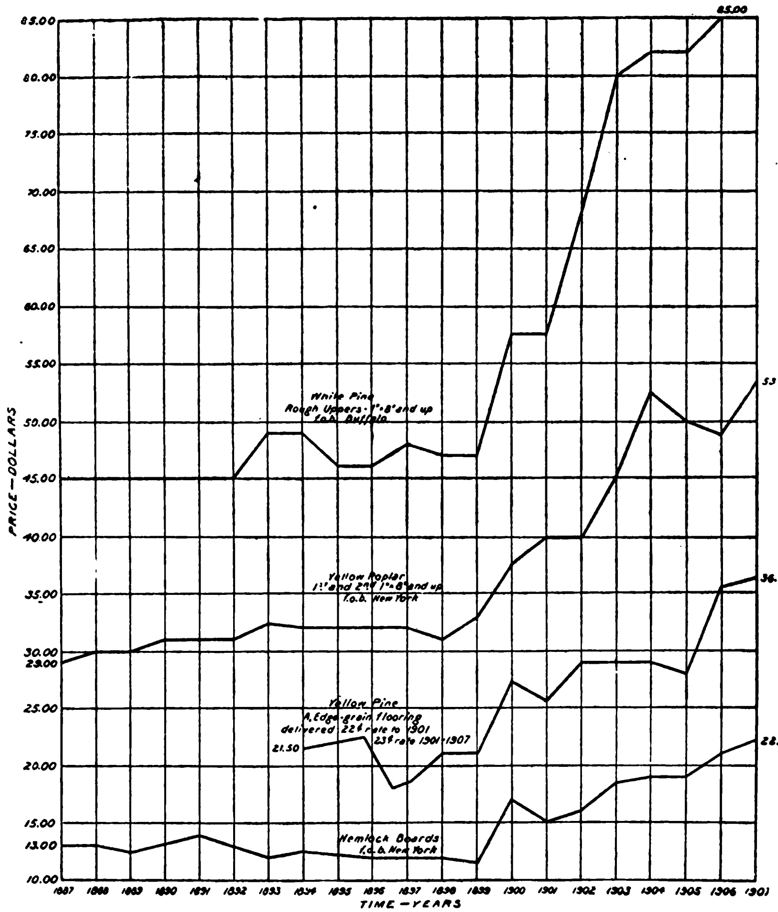


FIG. 2.—Range of lumber prices, 1887 to 1897.

TABLE 7.—*Forest areas.*

State.	Total wooded area.	National forests.	State forests.	Private and unreserved public forests.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Alabama	24,512,000			24,512,000
Arizona	16,000,000	9,463,725		6,356,275
Arkansas	28,800,000			28,800,000
California	28,608,000	a21,902,931		6,705,069
Colorado	21,440,000	15,748,722		5,691,278
Connecticut	1,216,000		1,360	1,214,640
Delaware	448,000			448,000
Florida	24,128,000			24,128,000
Georgia	26,880,000			26,880,000
Idaho	22,400,000	a20,336,427		2,063,573
Illinois	6,528,000			6,528,000
Indiana	6,912,000		2,000	6,910,000
Indian Territory	12,800,000			12,800,000
Iowa	4,480,000			4,480,000
Kansas	3,648,000	97,280		3,550,720
Kentucky	14,208,000			14,208,000
Louisiana	18,112,000			18,112,000
Maine	15,168,000			15,168,000
Maryland	2,816,000		3,500	2,812,500
Massachusetts	2,688,000			2,688,000
Michigan	24,320,000		39,000	24,281,000
Minnesota	33,408,000		21,000	33,387,000
Mississippi	20,672,000			20,672,000
Missouri	26,240,000			26,240,000
Montana	26,880,000	20,528,263		6,351,737
Nebraska	1,472,000	556,072		915,928
Nevada	3,904,000	a2,348,999		1,555,001
New Hampshire	3,328,000			3,328,000
New Jersey	2,069,760		1,800	2,067,960
New Mexico	15,168,000	a7,337,564		7,830,436
New York	11,968,000		1,439,988	10,528,012
North Carolina	22,592,000			22,592,000
North Dakota	384,000			384,000
Ohio	5,952,000			5,952,000
Oklahoma	2,816,000	60,800		2,755,200
Oregon	34,752,000	a16,463,535		18,288,465
Pennsylvania	14,848,000		820,000	14,028,000
Rhode Island	256,000			256,000
South Carolina	13,120,000			13,120,000
South Dakota	1,600,000	1,263,720		336,280
Tennessee	17,472,000			17,472,000
Texas	40,960,000			40,960,000
Utah	6,400,000	7,119,472		
Vermont	2,496,000			2,496,000
Virginia	14,976,000			14,976,000
Washington	30,528,000	a12,065,500		18,462,500
West Virginia	11,776,000			11,776,000
Wisconsin	20,320,000		254,063	20,065,937
Wyoming	8,000,000	9,020,475		
Total	700,469,760	144,313,485	2,582,711	554,313,511

*a*Approximate area.

Total National and State Forests, 146,896,196 acres, equal to 21 per cent. of the total wooded area.

Only one-fifth of our forest area is in National or State Forests; four-fifths is either in private hands or likely to pass into private hands. It has been shown that the present annual cut of forest products requires at least 20 billion cubic feet of wood. To produce this quantity of wood without impairing the capital stock our 700 million acres of forest must make an annual increment of 30 cubic feet per acre. Under present conditions of mismanagement and neglect it is safe to say that the average annual increment is less

than 10 cubic feet per acre for the entire area. This means that each year's cut at the present rate takes the growth of more than three years. The average age of the trees which are being felled for lumber this year is not less than 150 years. The lumberman could not afford to replace them were he blessed with the prospect of unequaled longevity, since such long investments are unprofitable for private capital. In consequence there arises the need that the State and National governments, which do not need to look for so high a rate of interest as the private investor and which are concerned with the promotion of the general welfare, should assume the responsibility of providing a future supply of timber.

The forest area of the United States is sufficient, if rightly managed, to produce eventually timber enough to supply every legitimate need. There is no reason why it should not some day be brought up to the point of yielding an annual increment of more than 30 cubic feet per acre, which, as previously said, would supply the quantity of timber now consumed, and which if used economically will be sufficient for a much increased population. The experience of Germany well illustrates the possibilities along this line. The following quotations from an article by Dr. B. E. Fernow, in Forestry and Irrigation for February, 1907, present the case clearly:

> One hundred and fifty years ago Germany found herself in very much the same condition as regards her forest resources as we are today in the United States—all accessible portions more or less culled, or in poor coppice, burnt over, and damaged by cattle, the valuable virgin timber mostly confined to distant and inaccessible locations. Sporadic attempts existed here and there at protection, at regulation of the cut, at conservative lumbering, and still more sporadic attempts at reforestation.
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> * * * * * * *
>
> Yet until the beginning of the nineteenth century reduction of supplies without adequate reproduction proceeded, and around the year 1800 the wood famine had become acute, giving rise to the same kind of agitation and literature which we have experienced, even to bringing in the catalpa and other such small, rapid growers as the saviors of the nation.

The severity of the timber shortage in Germany at that time was temporarily relieved through increased production of coal and the building of railroads into hitherto inaccessible forest regions. Then came the vigorous organization of extensive forest reserves and the adoption of a settled policy of forest management, based upon the principle of sustained yield, or the cutting of the increment only, without lessening the wood capital. The results of this policy were, in the words of Doctor Fernow, that—

In Saxony the cut increased during the years 1820 to 1890 just 50 per cent., and up to 1904 has increased by another 5 per cent., namely, to 93 cubic feet per acre, the increase through the whole period being at the rate of 0.5 per cent. annually.

In Prussia the increase is still more pronounced. While in 1830 the cut was 20 cubic feet per acre, and in 1865 increased to only 24 cubic feet, in 1890 it was 52, and in 1904 it had grown to 65 cubic feet; forest management had increased the average acre production in seventy-five years more than threefold.

* * * * * * *

An acreage of 15,600,000 of German State, municipal, and private forests, lately canvassed, produces an average net revenue of $2.40 per acre annually. In other words, every acre of this property, good, bad, and indifferent, productive and unproductive, represents a capital of $50, paying 5 per cent. interest, and this constantly improving.

It must not be overlooked that these results have come largely from non-agricultural lands, the sandy plains, the swamps, the rough mountain slopes, and from forests which in part, at least, were mismanaged like ours.

Can we expect to attain the same or similar results?

We ought to do much better, for we have the hundred years of experience of our friends across the water to draw on, and we can avoid many of the mistakes which they have naturally made and paid for.

Approved:
JAMES WILSON, Secretary.
Washington, D. C., April 16, 1907.

U. S. DEPARTMENT OF AGRICULTURE.
Forest Service—Circular 116.
GIFFORD PINCHOT, FORESTER.

The Waning Hardwood Supply and the Appalachian Forests

BY WILLIAM L. HALL,
Assistant Forester.

HARDWOOD CUT DECLINING.

The hardwood lumber cut in 1899, according to the census,[a] was 8,634,021 thousand feet; in 1906 it had fallen to 7,315,491 thousand feet, a decrease of 15.3 per cent.

This decrease took place during a period when American industries sprang forward at a pace unparalleled; when there was the strongest demand ever known for every class of structural material; when the output of pig iron increased 15 per cent., that of cement 132.17 per cent., and even that of softwood timber 15.6 per cent.

That the decrease is due to diminished supply rather than to lessened demand seems to be proved beyond question. During the same period the wholesale price of various classes of hardwood lumber advanced from 25 to 65 per cent.; every kind of hardwood found in quantity sufficient to make it useful has been put on the market, and hardwood timber is now being cut in every State and every locality where it exists in quantity large enough to be cut with profit. These conditions could not prevail were the decrease in production due to a falling off in demand.

CONDITION AS SHOWN BY KIND OF TIMBER.

The most notable shrinkage has been in the leading hardwoods to which the public has been long accustomed.

Oak, which in 1899 furnished over half the entire output of hardwood lumber, fell off 36.5 per cent. Yellow poplar, which in 1899 was second among hardwoods in quantity produced, fell off 37.9 per cent. Elm, the great standard in slack cooperage, went down 50.8 per cent. Cottonwood and ash, largely used in many industries, lost, respectively, 36.4 and 20.3 per cent.

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[a] The cut of 1899 was reported in the census of 1900. The reports for the years 1904 and 1905 are available, but are less complete, and are, therefore, not quite comparable with the above figures. In each case the figures for those years fall below those for 1906. Acknowledgment is made to the Bureau of the Census for other figures used in this report.

A complete comparison of output for the fifteen leading hardwoods in given in Table 1.

TABLE 1.—*The cut of hardwood lumber, by kinds, 1899–1906.*

Wood.	1899. Thousand feet.	1906. Thousand feet.	Per cent. increase (+) or decrease (—).
Oak	4,438,027	2,820,393	—36.5
Maple	633,466	882,878	+39.4
Poplar	1,115,242	693,076	—37.9
Red gum	285,417	453,678	+59.0
Chestnut	206,688	407,379	+97.1
Basswood	308,069	376,838	+22.3
Birch	132,601	370,432	+179.4
Cottonwood	415,124	263,996	—36.4
Beech	(a)	275,661	....
Elm	456,731	224,795	—50.8
Ash	269,120	214,460	—20.3
Hickory	96,636	148,212	+53.4
Tupelo	(a)	47,882	....
Walnut	38,681	48,174	+24.5
Sycamore	29,715	....	....
All other	208,504	87,637	—58.0
Total	8,634,021	7,315,491	—15.3

a Not separately reported.

The table shows clearly the three points already mentioned: First, several of the most important hardwoods are fast being exhausted. Second, the cut has increased in less known and less abundant woods. Maple increased 39.4 per cent. and rose to second place in the list. Red gum gained 59 per cent. and advanced from seventh to fourth place. Chestnut and birch have increased tremendously, and beech and tupelo have been prominently introduced. Third, although almost all possible new woods have been brought into use there has been a shrinkage in the total output of 15.3 per cent.

CONDITION AS SHOWN BY STATES.

An examination of the figures for certain States in which hardwood production has centered in the past shows a condition almost startling. Ohio, with a cut of 918 million feet in 1899, had fallen to 433 million in 1906; Indiana, with 976 million feet in 1899, had fallen to 446 million, and Tennessee's 862 million fell to 535 million. The condition can be realized by a study of Table 2, in which the hardwood cut is given by States for the years 1899 and 1906.

TABLE 2.—*Cut of hardwood lumber, by States, 1899–1906.*

States and Territories.	1899.	1906.	States and Territories.	1899.	1906.
	Thousand board feet.	*Thousand board feet.*		*Thousand board feet.*	*Thousand board feet.*
Alabama	105,491	66,409	New Jersey	31,871	18,665
Arkansas	444,102	528,970	New York	207,226	279,601
California	539	280	North Carolina	145,657	227,568
Colorado	75	2,035	North Dakota	2,030	....
Connecticut	77,594	86,949	Ohio	918,231	432,802
Delaware	6,319	8,290	Oklahoma	6,065	1,043
Florida	2,200	2,299	Oregon	2,529	6,971
Georgia	42,799	47,510	Pennsylvania	520,162	520,162
Idaho	....	3,383	Rhode Island	3,988	7,890
Illinois	250,361	127,269	South Carolina	17,483	18,232
Indiana	975,779	446,448	South Dakota	558	100
Indian Territory	9,378	20,141	Tennessee	861,874	535,115
Iowa	61,028	19,451	Texas	38,056	20,689
Kansas	....	170	Utah	....	71
Kentucky	734,386	615,256	Vermont	50,423	103,373
Louisiana	72,198	102,684	Virginia	239,860	267,196
Maine	28,730	73,156	Washington	5,703	785
Maryland	77,581	109,523	West Virginia	570,208	561,588
Massachusetts	42,147	62,270	Wisconsin	519,031	513,561
Michigan	811,649	783,241	Wyoming	....	220
Minnesota	61,956	29,071	Arizona, Nevada, New Mexico	....	....
Mississippi	207,322	286,168			
Missouri	442,236	314,093	Nebraska	14,428	....
Montana	1,300	5,084			
New Hampshire	23,468	59,709	Total	8,634,021	7,315,491

This table is convincing as to two things: First, the supply in Indiana and Ohio, the original center of hardwood production, is practically exhausted; second, the cut is now widely distributed and is heavy in every State where there are even small bodies of hardwoods.

Together with Illinois, Ohio and Indiana produced 25 per cent. of the hardwood in 1899. In 1906 they produced only 14 per cent. They can never regain their lead, or even maintain the standing they have. Their many wood-using establishments, which are now hard pressed for supplies, will exhaust their remaining remnants within a few years. The land which bore this timber, as fast as it was cleared, was turned to agricultural use, for which most of it is well suited. The improved farm lands of Indiana increased 10.4 per cent. between 1890 and 1900; those of Ohio, 4.9 per cent. In both States there is some waste land which will continue in timber and turn out local supplies, but not enough to have any considerable effect on the country's hardwood supply.

States not thought of in former years for their hardwoods are now turning out considerable quantities. Maine, with a cut of 29 million feet in 1899, went to 73 million in 1906; New Hampshire turned out 60 million in 1906 as against 23 million in 1899. Even Oregon, Montana, and other Western States came into the list with unexpected amounts. In all of the States west of the Mississippi

Valley the supply is small and can never become much of a factor.

The impressive thing is that we are bringing hardwoods from far and near, and still the cut is going down.

CONDITIONS IN MAIN REGIONS OF PRODUCTION.

The main production is now in the Lake States, especially Michigan and Wisconsin, the lower Mississippi Valley, and the Appalachian Mountains. What are the conditions in these regions?

LAKE STATES.

The three Lake States furnished 18 per cent. of the hardwood cut in 1906, as against 16 per cent. in 1899. This percentage increase does not mean a real increase. On the contrary, every one of the Lake States fell off, though altogether their cut did not decrease in proportion to that of the rest of the country. The figures seem to indicate unmistakably that their maximum production has been reached. If this is true, then their decline in the future is likely to be almost as rapid as that of Ohio and Indiana, because of the nearness of many large hardwood-using industries which will make heavy demands upon the supply. This is now the supply nearest to many of the great plants in Illinois, Indiana, and Ohio.

The hardwoods in the Lake States stand upon good loam soil which, though stony in places, produces the finest of grasses. Where arable, this soil yields good crops of hay and potatoes, and in some localities grain and fruit. So invariably do the hardwoods indicate good soil that they are one of the most common means of land classification. And since hardwood land always means good soil, land from which hardwoods are cut does not revert to the State, as has been frequently the case with pine land, especially in Michigan. The hardwood land is held until it can be sold to farmers who clear it and turn it permanetly to agricultural use, for which, as in Ohio and Indiana, it is fundamentally suited.

The southern part of Michigan, which originally bore magnificent hardwoods, was the first part of the State to be cleared, and is now the backbone of Michigan's agriculture. Just as fast as the hardwoods, even in the northern peninsula, are cut the land will be settled for farming. The same is true of Wisconsin and Minnesota. The almost complete exhaustion of their timber supply and the transformation of their hardwood lands into farms are apparently the only results to be expected.

LOWER MISSISSIPPI VALLEY.

The States of the lower Mississippi Valley, including Missouri, Arkansas, Texas, Louisiana, and Mississippi, produced in 1899 1,203,914 thousand feet, or 14 per cent. of the entire output, of hardwood lumber. In 1906 they produced 1,252,604 thousand feet, or 17 per cent. of the country's output. The percentage gain, it will be seen, represents a very slight absolute gain. Missouri and Texas declined somewhat, while Arkansas, Mississippi, and Louisiana made considerable increase. The figures indicate that this group of States has nearly, if not quite, reached its maximum cut. In these States, following the rule already noticed, the hardwoods are found on very fertile soil. They center in the lowlands—the river bottoms and the swamps. On account of their great fertility these lands are now desired for farming, and clearing, and even drainage where necessary, are being hastened in order to turn them to the production of cotton, corn, and other crops. An exception, of course, exists in the Ozark Mountains of Missouri and Arkansas, certain portions of which are better adapted to hardwood timber than to other uses. Such areas are relatively small. In the main, those mountains have a climate and a soil which adapt them to fruit growing, for which the Ozark section has already become noted. In common with the whole lower Mississippi Valley, this region must be expected to change largely from a timbered to an agricultural condition.

APPALACHIAN STATES.

The States which are here considered to form the Appalachian group are as follows: Maine, New Hampshire, Vermont, Massachusetts, New York, Pennsylvania, Maryland, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, and Alabama. They turned out in 1899, 3,667,495 thousand feet of hardwood, which was 42 per cent. of the total cut. In 1906 they produced 3,546,668 thousand feet, or 48 per cent. They thus increased their proportion 6 per cent., although they actually fell off 121 million feet.

While but small parts of several of these States lie in the mountains, it is true of the region as a whole that the bulk of their hardwood timber is now to be found in the mountains. The Appalachian Mountains must have fully half of the country's present supply of hardwood, in spite of the fact that heavy cutting has been going on in them for over a hundred years.

There are two main reasons why this region has borne such heavy

cutting and still contains so much of the supply. In the first place, the mountains are nonagricultural. There has been no wholesale tendency to clear them for farming. Profitable farming exists, as a rule, only in the valleys and on the lower slopes. Many sporadic attempts have been made to farm the higher mountains, especially in the Southern Appalachians, but the farms have been small and generally unprofitable. After the pioneers' patience or endurance has been exhausted the forest has slowly crept back and reclaimed the land, from which it never should have been removed.

In the second place, inaccessibility accounts for the continued forest character of the Appalachian region. With the low prices which prevailed until a few years ago, it did not pay to bring the timber down from the higher mountains. So it was allowed to remain.

While other causes may have had local influence, these conditions in the main account for the fact that the Appalachians have maintained their hardwood production. Nevertheless, some of the Appalachian States have gone back badly. Kentucky and Tennessee show heavy declines. In these States the lumbermen have gone farther and farther into the forest, until, even in the most inaccessible parts, little virgin growth remains.

It is only in the extreme portions of the mountains that the cut has held up or increased. Maine, New Hampshire, and Vermont in the North, and North Carolina in the South, show increased cuts. Not one of these States, however, shows anything like the production that Ohio, Indiana, Kentucky, or Tennessee has shown in the past.

The plain truth is that in the Appalachians, as in the other regions, the hardwood lumbermen are working upon the remnants. The supply is getting short and the end is coming into sight.

HOW LONG WILL THE SUPPLY LAST?

In view of existing situation, it is important to consider as closely as possible how long the hardwood supply will last. To reach any conclusion on this point we must know, approximately, how much hardwood we are using yearly, and we must know or estimate the available supply.

While we know within reasonably close limits how much hardwood is used for the manufacture of lumber, we do not know how much is cut for other purposes. Enormous quantities are required each year for railroad ties, telephone and other poles, piles, fence posts, and fuel, and a great amount is wasted in lumbering and

manufacture. The present lumber cut of 7 1-3 billion feet represents probably not one-third of the hardwoods yearly used. Twenty-five billion feet yearly is certainly not a high estimate.

The amount of standing hardwoods is still more uncertain. There has been no census of standing timber, and there have been but few estimates. The largest estimate sets the figure for hardwoods at 400 billion feet. If we are using hardwoods at the rate of 25 billion feet per year, this would mean a sixteen years' supply. The conditions during the past few years suggest no reason for increasing this estimate. A distinct difference exists between the softwood and the hardwood situation. The supply of softwoods east of the Mississippi is running low almost as fast as that of hardwoods. Of softwoods, however, a large supply exists on the Pacific coast, which will suffice for a number of years after the eastern supply is exhausted. There is no hardwood supply in the Far West. When the supply in the Central Eastern States is gone there will be no other source to which to turn.

ADVANCING PRICES OF HARDWOODS.

Only within the last eight years have prices begun to reflect the dwindling supply, though the immoderate cutting away of this resource has been going on for decades. The diagram (fig. 1) shows the advance in prices of some of the principal hardwoods during the past eight years. It also shows the almost steady level of prices previous to 1898.

Considering the impoverished supply and the tremendous demands on the part of all the industries for timber, there is nothing surprising about the increase, which seems not quite to have kept pace with the increasing prices of softwoods. This is rather remarkable in view of the shorter supply, but is probably due to the fact that softwoods, forming the main bulk of the lumber supply, have led in establishing prices.

Along with the increase of prices there has been an almost constant, and an entirely necessary, relaxation of the rules by which lumber is graded and sold. The latest and most significant change is that made by the National Hardwood Lumber Association at its meeting in Atlantic City in May, 1907. Heretofore only even lengths, such as 6, 8, and 10 and 12 feet have been upon the market. The changed rules allow even lengths down to 4 feet and 15 per cent. of odd lengths above 4 feet. Smaller standards of thickness are also allowed. Many other equally significant changes are included. It emphasizes the fact that we are down to the rock bot-

tom, and require every sound piece of hardwood lumber that can be put upon the market.

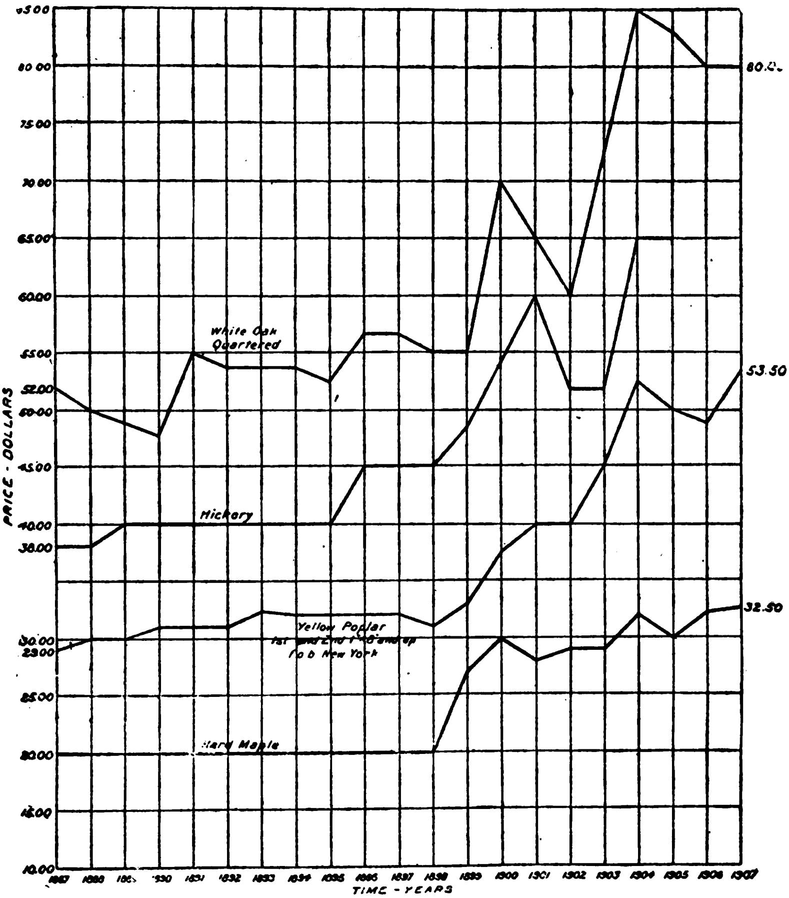

FIG. 1.—Increasing prices of hardwoods, 1887–1907.

WHAT INDUSTRIES WOULD A HARDWOOD SHORTAGE AFFECT?

Several great industries use hardwood timber mainly or almost exclusively for their raw material. Notable in this list are hardwood lumber manufacturing, the cooperage, furniture, and vehicle industries, and the industries engaged in the manufacture of musical instruments, coffins, and small wooden ware. All of these would suffer greatly and some would fail entirely upon the exhaustion of the hardwood supply. Other industries, such as the manufacture of agricultural implements, freight and passenger cars, boxes and crates, use immense quantities of hardwood.

HARDWOOD LUMBER MANUFACTURE.

Hardwood lumber manufacture affords an example of the damage already done. It has been shown how hardwood lumber production in Ohio was cut down over one-half between 1899 and 1906. The decrease in products between 1900 and 1905, according to census reports, amounted to $7,212,345, or 57.4 per cent., and the rank of the industry in the State fell from the fourth to the twentieth place. The number of employes fell from 10,689 to 6,442, or 40 per cent.

In Indiana during the same period the lumber industry fell from the third to the eighth place; the value of products decreased 27.1 per cent.; the number of wage-earners decreased 42.6 per cent., and the wages paid decreased 36.6 per cent.

Lumber manufacturing is the first among the industries to feel the blight of an exhausted timber supply. When the local supply ceases this industry must stop. Most other industries which use hardwoods can go on, bringing their supplies from a distance. Only with the failure of the entire supply are they seriously damaged.

COOPERAGE.

In much the same way the cooperage industry must be near the forest. Slack cooperage employs a great number of hardwoods and is distributed through many States. Tight cooperage makes use of the best grades of white oak almost exclusively and centers in Kentucky and Tennessee. The pressure of the timber supply is already heavy on this industry. If the oak supply should fail, the tight cooperage industry will largely cease, and some other container for liquids will have to be found to replace wood. As yet little progress has been made in securing substitutes for the oak cask and barrel.

FURNITURE MAKING.

The manufacture of furniture probably calls for more hardwood than any other industry, and employs hardwood almost exclusively as raw material. In 1905 there were 2,482 furniture establishments in the United States, with a capital of $153,000,000 and an annual product valued at $170,000,000. In reports made to the Forest Service 538 of these establishments reported the annual use of 580 million feet of lumber. It seems probable that the industry requires upward of 20 per cent. of the entire hardwood production. The public is so much accustomed to hardwood furni-

ture that furniture of any other material would not be acceptable. Failure of the hardwood supply would doubtless terminate the furniture industry as it is now carried on.

MUSICAL INSTRUMENTS.

As in furniture, hardwood is the chief material in the manufacture of musical instruments, especially pianos and organs. Maple, poplar, elm, oak, chestnut, and basswood are most largely used. Foreign woods are used only for veneers, for which purpose large quantities are not required.

VEHICLE MANUFACTURE.

In 1905 there were in the United States 5,143 establishments for the manufacture of vehicles, with a capital of $149,000,000 and a yearly product of $155,000,000. No industry stands in a more threatened position, so far as supply is concerned, than the manufacture of wagons and carriages. It requires the best hardwoods, end even now these are obtained with extreme difficulty. Hickory and oak are used in the largest quantities, and vehicle manufacturers believe that the hickory supply of the country can not last over ten years longer. Attempts to substitute other woods or other materials for hickory in vehicle manufacture have largely failed. The vehicle industry, like the furniture industry, can not exist on its present basis without hardwood timber.

AGRICULTURAL IMPLEMENTS.

Metal has to some extent taken the place of wood in farm implements, but surprisingly large quantities of hardwood are still used. Recent reports from 167 manufacturers show the use of 212,613,000 feet of lumber annually, by far the larger part of which is hardwood. Since in 1905 there were 648 manufacturing establishments in the United States, the quantity used must really be very great. Hardwood will undoubtedly be used in this industry as long as it is available.

CAR BUILDING.

Car building has required, and still requires, an enormous amount of hardwood material. Though steel is being employed more largely than in the past in the construction of both freight and passenger cars, the great majority of both classes of cars are still made of wood and the specifications of the railroads indicate that much of the timber used is hardwood.

RAILROAD TIES.

Hardwoods have been, and still are, most essential for railroad ties. Half of the hundred million ties used yearly are of hardwood. Hundreds of patents exist for ties of other material. None has commended itself to railroads as a general substitute for the wooden tie. Very large quantities of hardwood are likewise used for bridges and trestle work.

TELEPHONE AND OTHER POLES.

The pole lines of the country have also called for a great deal of hardwood timber. Every year the demand is increasing. No other material has proved satisfactory for the support of the network of wires which now binds together every part of the country.

HOUSE FINISHING.

House finishing, including interior woodwork, doors, window sashes, stair work, and mantels consumes each year a great deal of hardwood. For durability and acceptability hardwood finds here one of its most desirable uses. In well-built houses in many parts of the country hardwood finishing is almost as commonly found as is hardwood furniture.

WHAT STATES WOULD BE MOST AFFECTED.

Below is given a tabular statement showing the rank of the most important States in the leading hardwood industries, as shown by the census reports. The rank is based upon value of products, except in lumber manufacturing, where it is based on quantity of product.

TABLE 3.—*Rank of most important States in hardwood industries.*

Industry.	Illinois.	Indiana.	Ohio.	New York.	Michigan.	Pennsylvania.
Lumber manufacture (census 1900)a	....	1	2	....	4	....
Planing mills	3	....	4	1	5	2
Agricultural implements	1	6	3	2	5	....
Carriages and wagons	5	2	1	3	4	....
Furniture	2	4	5	1	3	....
Car building	1	4	....	....	3	2
Musical instruments	2	....	....	1	....	....

aThe census of 1900 is used in order to show the rank of Indiana and Ohio before their timber supply declined.

The statement shows how substantially the hardwood industries center in the States of Illinois, Indiana, Ohio, Michigan, and New York. Of these only Michigan and New York have now any con-

siderable hardwood supply of their own. Illinois, Indiana, and Ohio are dependent upon the Lake States, the lower Mississippi Valley States and the Appalachian States.

The main consideration, however, is that if the hardwood timber supply were to be speedily exhausted the great industries which now depend upon it would be severely crippled or ruined. To consider how important these are, take, for instance, the State of Illinois. Though Illinois is not known as an important hardwood State, Table 3 shows it to be second only to New York in hardwood manufacturing industries. In these industries Illinois has invested, according to the census of 1905, a capital of $148,115,805—almost one-fifth of the total capital invested in manufacturing. It employs 59,844 wage-earners, and it turned out, in 1905, a product valued at $139,970,590, or 12 per cent. of the total value of manufactured products.

Exhaustion of the hardwood supply assuredly means the loss of these industries to the States in which they are at present located, just as Ohio and Indiana have already lost the main part of their hardwood lumber manufacturing. Such industries can not exist after their supply of raw material is gone.

SITUATION CONCERNS ENTIRE COUNTRY.

How intensely the whole country would feel the loss of its hardwood timber, to an ample supply of which it has long been accustomed, can scarcely be realized. Without hardwood for building purposes, for railroad ties, for the manufacture of furniture, cooperage, and vehicles, and for the varied other uses to which it is put, we should be in sad straits indeed. A general failure in crops may affect industrial conditions for a few years—a failure in the hardwood supply would be a blight upon our industries through more than a generation. The situation in brief is this: We have apparently about a fifteen years' supply of hardwood lumber now ready to cut. Of the four great hardwood regions, the Ohio Valley States have been almost completely turned into agricultural States, and the Lake States and the Lower Mississippi Valley are rapidly following their example.

In the Appalachian Mountains we have extensive hardwood lands which have been culled and greatly damaged by fire. These are practically all in private hands, and while they contain a large amount of inferior young timber, they are receiving little or no protection, and even such young timber as exists is making but slight growth. Even if these cut-over lands be rightly managed

they can not greatly increase their yield of merchantable timber inside of from thirty to forty years.

The inevitable conclusion is that there are lean years close ahead in the use of hardwood timber. There is sure to be a gap between the supply which exists and the supply which will have to be provided. How large that gap will be depends upon how soon and how effectively we begin to make provision for the future supply. The present indications are that in spite of the best we can do there will be a shortage of hardwoods running through at least fifteen years. How acute that shortage may become and how serious a check it will put upon the industries concerned can not now be foretold. That it will strike at the very foundation of some of the country's most important industries is unquestionable. This much is true beyond doubt, that we are dangerously near a hardwood famine and have made no provision against it.

THE SOLUTION.

If it is true that the hardwood supply is approaching a condition of shortage which would paralyze many of the great industries and gravely affect the entire country, then it is important to seek diligently the best means to avert it, or if that is not wholly possible, to reduce its injuries to the minimum.

The belief is common that the substitution of softwood, metal, and concrete for hardwood will gradually take place as the supply of the latter is reduced. Already the substitution of metal has made much progress. It has replaced hardwood to a considerable extent in the manufacture of implements, furniture, and cars, and even in the interior finish of office buildings and in general construction work. Concrete has also come into wide use in construction. Yet, prominent as these materials have become, they seem not to have reduced the demand for hardwood, which, besides being retained for the greater number of its original uses, has also found new ones. There is not now much tendency for soft woods to replace hardwoods, and there is not likely to be, because they have not the strength or other properties to make them acceptable as substitutes. The replacement of hardwood by other materials is to be welcomed where those materials make for better service and cheaper cost. Where they will not, and experience thus far shows this list to be a large one, the problem of a hardwood shortage must be solved in another way.

There seems to be but one practicable solution, and that is to maintain permanently under a proper system of forestry a suffi-

cient area of hardwood land to produce by growth a large proportion of the hardwood timber which the nation requires.

Where is this land to be found? Not in the Ohio Valley, the Lakes States, or the Mississippi Valley, for the reasons already given. It is to be found in the Appalachian Mountains. These mountains increased their proportion in the nation's hardwood output from 42 to 48 per cent. during the past seven years. On the principle of using the land for its highest purpose they should further increase their proportion to not less than 75 per cent. Other sections of the country will readily furnish the remaining 25 per cent.

APPALACHIANS THE KEY TO THE SITUATION.

The mountain ranges from Maine to Alabama should be made to produce the greater part of the hardwood supply, because growing hardwood timber is their most profitable use. There is, in fact, no other use to which the surface of these mountains can permanently be put. That they can not be successfully farmed has been proved in thousands of cases. For the most part they can not even be permanently grazed.

It is in the production of timber that they excel. They bear the greatest variety of species and the best remaining hardwood growth anywhere to be found. Freed from their enemies—fire and unwise cutting—their forests readily reproduce the best kinds of timber. Outside of local areas of the Pacific coast nowhere else is forest growth so rapid. Even land cleared and farmed to the complete exhaustion of its soil will in this region in time reclothe itself with forests, if only it is protected.

Field estimates by counties show that south of Pennsylvania there are in the Appalachians 58 million acres of forest land, practically all of which is covered by hardwood and over 85 per cent. of which is in a cut-over or culled condition. Including the mountains of Pennsylvania, New York, and New England it is probably safe to estimate that the entire Appalachian area includes as much as 75 million acres primarily adapted for hardwood timber. Only a very small part of this is still in virgin growth. By far the greater part of it has been cut over, and some of it has been cleared.

Well managed and protected from fire, this area has enormous producing powers. Studies by the Forest Service of average virgin and cut-over lands in eastern Tennessee show that under protection these lands are capable of producing 50 cubic feet of wood per acre annually. Even taking the production as 40 cubic feet, this means

for the area of 75 million acres a possible annual production of 3 billion cubic feet.

How does this compare with the annual requirements? The 25 billion feet, board measure, used annually (allowing a product of 8 feet B. M. for each cubic foot, which is believed to be not too high under present utilization) represents a little over 3 billion cubic feet. This is just about equal to the amount which the Appalachian forest is capable of producing. When it is remembered that the Appalachians will probably not be called upon to furnish more than three-fourths of the total supply, it is clear that there is a good margin of safety. Therefore, if the Appalachian forests are rightly managed and taken soon enough, they will insure continuously the hardwood supply of the country, and do it without exhausting the forest. In fact, it can be done so that the systematic treatment will at the same time improve the forest.

Our experience will doubtless be the same in this respect as that of Germany.* In Saxony the cut, which represents only the growth, increased during the period from 1820 to 1904 55 per cent, bringing the annual yield to 93 cubic feet per acre. Prussia shows a still more pronounced increase. In 1830 the cut was only 20 cubic feet per acre, and in 1865 had increased to only 24 cubic feet. But in 1890, owing to proper management, it had risen to 52, and in 1904 to 65 cubic feet. These results came largely from nonagricultural lands, sandy plains, swamps, and rough mountain slopes, and from forests which had been mismanaged, much the same as ours.

Much of the Appalachian forest has been so damaged that years will be required for it to reach again a high state of productiveness. Its present average production is probably not over 10 cubic feet per acre per year. The increase would of course be gradual and it would be slow at first. It would be some time before it could average the 40 cubic feet per acre used in the above estimate. Until it does we can expect a shortage in hardwood timber. The longer the delay in putting this forest under control, the longer continued and more extreme will be the shortage.

Approved: JAMES WILSON, Secretary of Agriculture.

*From article by Dr. B. E. Fernow, Forestry and Irrigation, February, 1907.

U. S. DEPARTMENT OF AGRICULTURE,
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GIFFORD PINCHOT, FORESTER.

The Lumber Cut of the United States in 1905

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During the past year the Forest Service has for the first time attempted to gather detailed statistics of the lumber cut of the United States. This task was undertaken in cooperation with the National Lumber Manufacturers' Association, whose members cut at least one-third of the lumber annually manufactured in the United States. The work was done almost entirely through correspondence. It was new and unfamiliar both to those who had it in charge and to the reporting manufacturers. The resulting figures, secured in spite of these handicaps, while not complete, are certainly as nearly complete as could have been expected.

The first request for statements of cut was sent to the manufacturers early in January, 1906. To those who failed to report, a second request was sent in March, and a third in April. At the annual meeting of the National Lumber Manufacturers' Association, in St. Louis, May 9, a preliminary tabulation covering 27,738,000,000 feet of lumber, cut by 11,232 firms, was presented. Subsequently other manufacturers reported, and some additional figures for delinquent firms were furnished by the North Carolina Pine Association, the Yellow Pine Manufacturers' Association, the Southern Cypress Association, the Northern Pine Manufacturers' Association, the Western Pine Manufacturers' Association, the Pacific Coast Lumber Manufacturers' Association, and the Forest, Fish, and Game Commission of New York. The information given by the two organizations last named was so full that the data for the States of Washington and New York are practically complete.

The final tabulation shows that 11,666 establishments cut 30,502,961,000 feet of lumber in 1905. According to these figures both the number of establishments and the total cut are lower than the Census showing for 1899 and for 1904. The Census figures do not cover custom mills, while a few such mills are included in the Forest Service reports. In Table 1 the statements for the three years are printed side by side. In the right hand column of this table is given the ratio which the figures for 1905 bear to those of 1904.

TABLE 1.—*Comparison of Census figures upon the lumber cut of the United States in 1899 and 1904 with those of the Forest Service for 1905.*

Product.	Census, 1899 (23,053 establishments).	Census, 1904 (19,127 establishments).	Forest Service, 1905 (11,666 establishments).	Ratio of Service figures for 1905 to Census figures for 1904 (establishments 61.0 per cent.).
	M feet.	*M feet.*	*M feet.*	*Per cent.*
Yellow Pine	10,231,140	12,812,207	9,760,508	76.0
White pine	7,349,108	5,253,846	5,106,783	97.3
Douglas fir	1,725,968	2,929,534	4,319,449	147.2
Hemlock	3,285,045	3,268,787	2,804,083	85.8
Oak	3,848,363	2,902,855	1,833,769	63,2
Spruce	1,409,333	1,303,886	1,165,940	89.7
Yellow poplar	1,042,380	853,554	582,748	68.3
Cypress	492,761	749,592	753,269	100.5
Maple	605,654	587,558	608,746	103.7
All others	3,475,098	3,473,220	3,567,566	102.8
Total	33,464,850	34,135,139	30,502,961	89.0

The incompleteness of the returns for 1905 does not wholly explain the lower figures for that year, especially as to the number of establishments. The cut of 1905 in the Forest Service figures is 89.0 per cent. of the Census figures for the cut of 1904, but the establishments reporting to the Service numbered but 61.0 per cent. of those given in the Census. The establishments which failed to report to the Service were, however, mainly small ones. Thus, though the failure of many establishments to report has necessarily kept the given total cut below its true figure, the delinquent reports, if obtained, would not raise the given total cut proportionately.

A second fact to be borne in mind is that the actual number of establishments is on the decline. This is borne out by the Census figures of 1899 and 1904, which show a falling off of nearly 4,000 in the number of establishments during the period. During the same period the total cut increased, though not greatly. Had the number of establishments reporting to the Service in 1905 borne the same relation to those reporting to the Census in 1904 as the latter bore to those reporting to the Census in 1899, the Service figures for total cut would doubtless have shown a similar, perhaps a greater, increase. For the establishments of 1904 numbered 82.9 per cent. of those of 1899, while those of 1905, as already noted, numbered only 61.0 per cent. of those of 1904.

In other words, there is a clear tendency toward a reduction in number of establishments, together with a gain in individual output. Two causes account for this tendency—the end of supply is being reached in some localities, particularly with white pine stumpage in the Lake States, and the concentration of capital, as in

other industries, is resulting in the consolidation of plants in fewer hands.

Not all sections of the country, and, consequently, not all woods, are proportionately represented in the figures. Many of the operators of rather small hardwood mills in the Central States and of yellow pine mills in the Southern States did not report, and even the aid of association secretaries failed to secure data from them.

The Census gives the total value of the lumber cut of the United States in 1904 as $435,708,084. There was a marked rise in lumber prices in 1905, however; so it is safe to say that the value at the mills of the cut for that year was between $475,000,000 and $500,000,000.

SUMMARY OF PRODUCTION.

The total cut of yellow pine was probably little, if any, greater in 1905 than in 1904. The cut of white pine was certainly no greater. The cut of Douglas fir increased remarkably, because the capacity of old mills was increased and many new ones were added. The cut of fir in 1904 was also below normal, owing to unfavorable market conditions. There was probably a small decrease in hemlock. There was probably a slight decrease in the cut of spruce. The Census shows a decrease of 34 per cent. in oak from 1899 to 1904, and this decrease is undoubtedly continuing. There was also some decrease in poplar, a continuation of the decrease of 18 per cent. shown in the Census returns between 1899 and 1904. There was evidently an increase in cypress, maple, and the miscellaneous group, including a large number of species of minor importance, many of which are being substituted for those which are obtained with increasing difficulty.

Table 2 gives the kind and quantity of lumber cut by the 11,666 establishments from which the Forest Service received reports. Yellow pine is far in the lead, with 8,771,966,000 feet, or 28.8 per cent. of the total cut; and this lead would have been increased to at least 34 per cent. if full reports had been secured. White pine follows, with 4,868,020,000 feet, or 16 per cent.; next Douglas fir, with 4,319,479,000 feet, or 14.2 per cent.; then hemlock, with 2,804,083,000 feet, or 9.3 per cent. The relative rank of the various species is shown graphically in figure 1.

TABLE 2.—*Kind and quantity of lumber cut in the United States in 1905 by 11,666 mills.*

Kind.	M feet.	Per cent.	Kind.	M feet.	Per cent.
Yellow pine	8,771,966	28.8	Cottonwood	236,000	0.8
White pine	4,868,020	16.0	Elm	227,038	.7
Douglas fir	4,319,479	14.2	Chestnut	224,413	.7
Hemlock	2,804,083	9.3	Beech	219,000	.7
White oak	1,210,216	4.0	Ash	159,634	.5
Spruce	1,165,940	3.8	Sugar pine	123,085	.4
Western yellow pine	988,542	3.2	Western white pine	115,678	.4
Cypress	753,369	2.5	Hickory	95,803	.3
Red oak	623,553	2.0	Other kinds	294,512	1.0
Maple	608,746	2.0	Mixed	519,865	1.7
Poplar	582,748	1.8			
Redwood	411,689	1.3	Total softwoods	24,914,618	81.3
Cedar	363,900	1.2	Total hardwoods	5,588,343	18.7
Red gum	316,588	1.0			
Basswood	258,390	.9	Grand total	30,502,961	100.0
Birch	240,704	.8			

The rapid reversal which is taking place in the positions of white pine and Douglas fir is shown by the fact that in 1899 the former produced 21.5 per cent. of the lumber cut and in 1905 only 16 per cent., while the latter, which produced only 5 per cent. in 1899, in

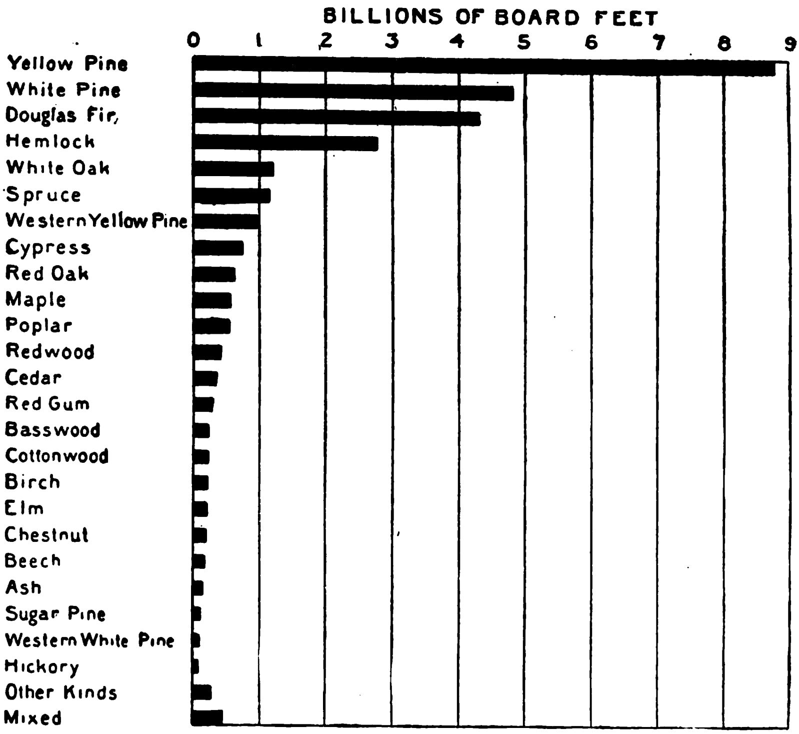

FIG. 1.—Lumber production, by species, 1905.

1905 produced 14.2 per cent. The other species are given in order of importance. The kinds not specified include larch, tamarack. tupelo, balsam, and walnut, which are cut in relatively small amounts. The detailed figures for them will be found in Tables 28 and 29. The heading "Mixt" includes all reports which did not give the kind of timber cut or which gave it in such a way that the amounts of several species could not be determined. It may, however, be safely assumed to be practically all hardwood. The table shows that the amount of softwood reported was 24,914,618,000 feet, or 81.3 per cent. of the total cut, and that the amount of hardwood reported was 5,588,343,000 feet, or 18.7 per cent. of the total cut. In 1899 the softwoods furnished about 75 per cent. of the total and the hardwoods about 25 per cent. The changed ratio is due mostly to the increased cut of yellow pine and Douglas fir and the falling off in oak and poplar.

TABLE 3.—*States which produced over 100,000,000 feet of lumber in 1905; reports from 11,666 mills.*

State.	M feet.	Per cent.	State.	M feet.	Per cent.
Washington	3,917,166	12.8	Florida	658,007	2.2
Wisconsin	2,543,503	8.3	Tennessee	540,920	1.8
Louisiana	2,293,809	7.5	South Carolina	466,478	1.5
Minnesota	1,925,804	6.3	Kentucky	464,676	1.5
Michigan	1,719,687	5.6	Missouri	362,217	1.2
Arkansas	1,488,589	4.9	Indiana	352,362	1.2
Pennsylvania	1,397,164	4.6	New Hampshire	340,727	1.1
Mississippi	1,299,390	4.3	Ohio	331,552	1.1
Oregon	1,262,610	4.1	Vermont	266,676	.9
North Carolina	1,080,602	3.5	Massachusetts	252,804	.8
California	1,061,608	3.5	Idaho	212,725	.7
Texas	929,863	3.1	Montana	189,291	.6
Alabama	843,897	2.8	Maryland	163,749	.5
New York	750,280	2.5	Iowa	129,472	.4
Maine	745,705	2.5	Illinois	119,065	.4
Virginia	715,197	2.4	All others	292,060	.9
Georgia	712,604	2.3			
West Virginia	672,902	2.2	Total	30,502,961	100.0

Table 3 gives the 33 States which produced over 100,000,000 feet of lumber each, according to the reports received by the Forest Service. Washington leads with 3,917,166,000 feet, or 12.8 per cent. of the total amount reported, followed by Wisconsin with 2,543,503,000 feet, or 8.3 per cent.; next Louisiana, with 2,293,-809,000 feet, or 7.5 per cent.; then Minnesota, with 1,925,804,000 feet, or 6.3 per cent.; and fifth Michigan, with 1,719,687,000 feet, or 5.6 per cent. From no other State does the amount reported exceed 5 per cent. of the total. The 11 States which reported a cut of over 1,000,000,000 feet each, produced two-thirds of the lumber reported for the entire United States. The relative rank of the 33 States given in Table 3 is shown graphically in figure 2.

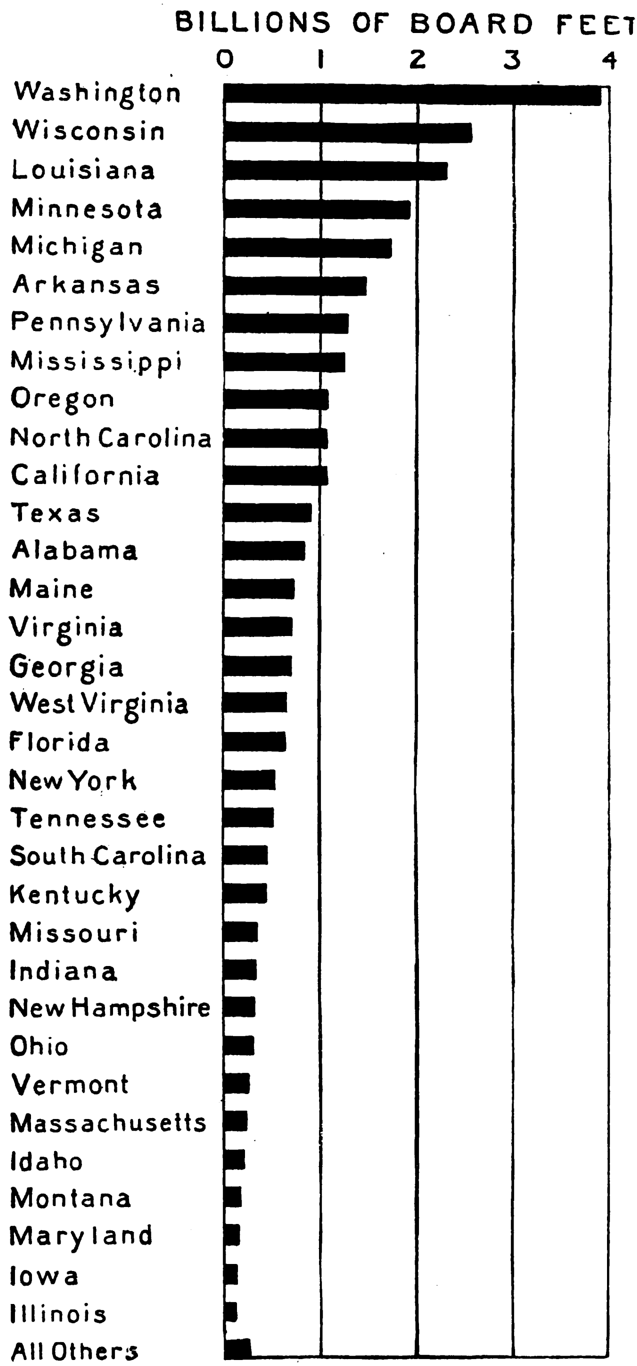

FIG 2.—Lumber production, by States, 1905

It is interesting to note that the five leading States in the production of lumber in 1899 were Wisconsin, with 10 per cent. of the total; Michigan, with 9.6 per cent.; Minnesota, with 7.7 per cent.; Pennsylvania, with 6.3 per cent.; and Washington, with 5.3 per cent. During the past five years Washington has advanced from fifth to first place, a position it will assuredly hold for a long time.

Figure 3 gives in order of rank the eight States which have led in lumber production since 1850. From this it is seen New York occupied first place in 1850, Pennsylvania in 1860, Michigan in 1870, 1880 and 1890, Wisconsin in 1900 and 1904, and Washington in 1905. This chart is based upon Census reports, except for 1905, for which Forest Service figures are used. Previous to 1900, data are lacking concerning the quantity of lumber cut in the various States, and the rank is based on value, while for 1900, 1904 and 1905 it is based on the total cut.

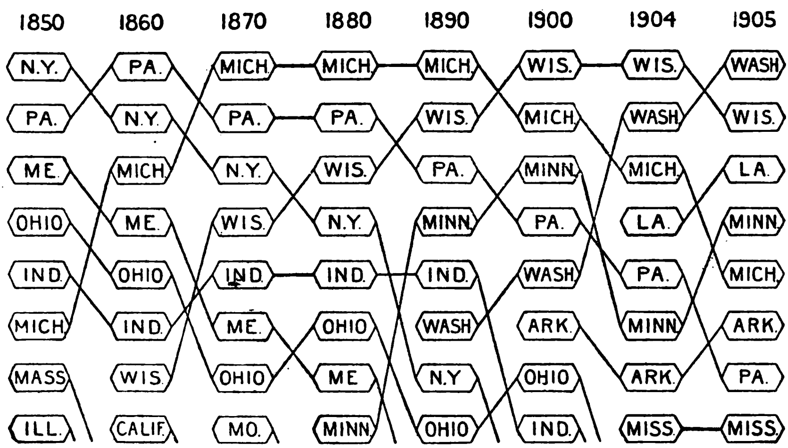

FIG. 3.—Relative rank of the eight States leading in the production of lumber since 1850.

PRODUCTION BY SPECIES.

Tables 4 to 28 give the quantity of each kind of lumber cut in the various States in the order of relative importance, as indicated by the reports to the Forest Service. It should be borne in mind that the total number of mills given in these tables far exceeds the total given in Table 29. If, for instance, a mill cuts oak, ash, hickory, and gum it appears in the tables for each of these species.

YELLOW PINE.

The term "yellow pine" covers all of the pine in the eastern half of the United States except white and Norway pine. The principal species included are, in order of importance, longleaf, shortleaf, loblolly, and pitch pine.

In 1905, 3,162 mills, as shown by Table 4, reported a cut of 8,771,966,000 feet of yellow pine. It will be seen from the table that Louisiana leads, with 1,737,960,000 feet, or 19.8 per cent. of the total. Then comes Arkansas, with 1,024,011,000 feet, or 11.7 per cent.; Mississippi, with 1,017,191,000 feet, or 11.6 per cent.; Texas, with 910,465,000 feet, or 10.4 per cent.; North Carolina, with 837,366,000 feet, or 9.5 per cent.; Alabama, with 744,192,000 feet, or 8.5 per cent.; Georgia, with 663,831,000 feet, or 7.6 per cent.; Florida, with 601,374,000 feet, or 6.9 per cent.; Virginia, with 496,895,000 feet, or 5.7 per cent.; and South Carolina, with 406,502,000 feet, or 4.6 per cent. These ten States produced over 96 per cent. of the total amount of yellow pine reported. A relatively small amount was cut in Missouri and Maryland, and a little was reported from sixteen other States.

The annual cut of yellow pine has probably not yet reached its maximum, and this timber will undoubtedly hold first rank in the point of output for several years.

Table 4.—*Cut of yellow pine in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Louisiana	168	1,737,960	19.8	Virginia	340	496,895	5.7
Arkansas	235	1,024,011	11.7	South Carolina	191	406,502	4.6
Mississippi	241	1,017,191	11.6	Missouri	63	161,128	1.8
Texas	153	910,465	10.4	Maryland	77	85,023	.9
North Carolina	551	837,366	9.5	All others	410	86,028	1.0
Alabama	290	744,192	8.5				
Georgia	326	663,831	7.6	Total	3,162	8,771,966	100.0
Florida	117	601,374	6.9				

WHITE PINE.

The cut of white pine by States is given in Table 5. White pine in greater or less quantity was reported from twenty-four States. Norway or red pine is included with white pine, since the two species are cut and sold together under the name of "northern pine" in the Lake States, and it is impossible to determine exactly the proportion of Norway. It is safe to say, however, that at present at least 30 per cent. of the pine cut in Michigan, Wisconsin, and Minnesota is Norway pine, or over 1,000,000,000 feet annually.

TABLE 5.—*Cut of white pine in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Minnesota	128	1,847,072	37.9	Pennsylvania	366	87,097	1.8
Wisconsin	289	1,467,078	30.1	Illinois	4	32,794	.7
Michigan	252	463,308	9.5	West Virginia	46	31,450	.7
New Hampshire	248	211,586	4.3	North Carolina	77	28,438	.6
Maine	299	201,867	4.1	Virginia	51	22,200	.5
Massachusetts	226	176,340	3.6	All others	256	65,878	1.4
Iowa	7	122,757	2.5				
New York	728	110,155	2.3	Total	2,977	4,868,020	100.0

The table shows that 2,977 firms reported a cut of 4,868,020,000 feet of white and Norway pine. Minnesota is the leading State, with 1,847,072,000 feet, or 37.9 per cent. of the total. Wisconsin comes second with 1,467,078,000 feet, or 30.1 per cent. Michigan stands third, with 463,308,000 feet, or 9.5 per cent. Then follow New Hampshire, Maine, Massachusetts, and other States. It will be noted that Iowa is credited with 122,757,000 feet and Illinois with 32,794,000 feet. This lumber was cut in mills along the Mississippi from Minnesota logs, and if Minnesota is credited with this timber, the output of white and Norway pine in the Lake States was over 80 per cent. of the entire cut of these species. The Census figures upon the cut of white and Norway pine in these three States in 1899 were: Wisconsin, 2,412,688,000 feet; Minnesota, 2,253,391,000 feet; and Michigan, 1,274,923,000 feet—a total of 5,941,002,000 feet, against 3,777,458,000 feet in 1905. The falling off has been greatest in Michigan, but the turning point has been passed even in Minnesota, and a decreasing output of pine can be looked for from the Lake States from year to year.

DOUGLAS FIR.

Douglas fir now ranks third in importance as a lumber producer in the United States, and it will hold second place within a short time. It is unfortunate that this species has so many names. "Red fir," "Douglas spruce," "yellow fir," and "Oregon pine" are other terms given it, and confusion is constantly arising in consequence. All are more or less justified by the circumstances that, botanically, the tree is neither a fir, a spruce, nor a pine. The cut for 1905, 4,319,479,000 feet, is given in Table 6. Of this amount, 427 mills in Washington cut 3,125,325,000 feet, or 72.4 per cent., and 281 mills in Oregon cut 1,076,695,000 feet, or 24.9 per cent. California reported 100,816,000 feet, and 16,643,000 feet was reported from five other western States.

There is a large amount of Douglas fir stumpage in Washington and Oregon, and the cut of this species will largely increase in the near future. In fact, the output of Douglas fir promises before many years to equal that of southern yellow pine and eventually to surpass it as the stumpage of the latter is reduced.

TABLE 6.—*Cut of Douglas fir in 1905.*

State.	Number of mills.	M feet.	Per cent.
Washington	427	3,125,325	72.4
Oregon	281	1,076,695	24.9
California	64	100,816	2.3
All others	24	16,643	.4
Total	796	4,319,479	100.0

HEMLOCK.

The amount of hemlock cut last year by 3,023 mills was 2,804,-083,000 feet, practically one-third of the total output, followed by Wisconsin, with 610,225,000 feet, or 21.8 per cent.; and Michigan, with 569,810,000 feet, or 20.3 per cent.; the three States producing three-fourths of the total quantity reported. Only a relatively small proportion was cut in any other State, but the production was widely scattered, as may be seen from the fact that returns were received from twenty-six States.

TABLE 7.—*Cut of hemlock in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Pennsylvania	415	920,854	32.8	Maine	257	86,753	3.1
Wisconsin	241	610,225	21.8	Washington	42	84,773	3.0
Michigan	299	569,810	20.3	All others	763	182,474	6.5
New York	1,006	179,550	6.4				
West Virginia	111	169,644	6.1	Total	3,023	2,804,083	100.0

It is of particular interest to note that 84,773,000 feet of hemlock was reported from the State of Washington. This is the western species, the lumber of which is freer from defects and of higher quality than that of the eastern species. So great has been the prejudice against the name "hemlock" in the West, however, that until very recently hemlock lumber has been mixed in with other lumber or sold under names which disguised its identity. The actual cut of western hemlock in 1905 was undoubtedly greater than the amount reported. The Census gave a cut of only 204,000 feet of this species for Washington in 1899, which indicates the difficulty of securing accurate figures upon it.

SPRUCE.

No attempt was made to distinguish the different kinds of spruce in the reports, but it will be understood, of course, that the spruce of Washington is different from that of Maine, and that altogether several species are cut for lumber. It is probable that a small amount of Douglas fir was reported as spruce by western operators.

TABLE 8.—*Cut of spruce in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Maine	238	358,758	30.7	Oregon	23	57,208	4.9
New York	329	211,076	18.1	Massachusetts	39	31,980	2.8
Washington	70	179,864	15.4	All others	244	48,622	4.2
Vermont	244	111,650	9.6				
West Virginia	35	107,072	9.2	Total	1,333	1,165,940	100.0
New Hampshire	111	59,710	5.1				

In 1905, 1,133 mills cut 1,165,940,000 feet of spruce, as shown by Table 8. Maine is far in the lead, as it has been for many years. The quantity reported from Maine for 1905 was 358,758,000 feet, or 30.7 per cent. of the total. New York comes next with 211,076,000 feet, or 18.1 per cent., followed by Washington with 179,864,000 feet, or 15.4 per cent.; Vermont with 111,650,000 feet, or 9.6 per cent.; West Virginia with 107,072,000 feet, or 9.2 per cent., and New Hampshire with 59,710,000 feet, or 5.1 per cent. Oregon reported 4.9 per cent. of the total, Massachusetts 2.8 per cent., and all other States combined 4.2 per cent. Altogether the cutting of spruce was reported from twenty-four different States.

WESTERN YELLOW PINE.

This is another species, concerning the trade name of which unfortunate difficulties have arisen. Botanically it is *Pinus ponderosa,* and is classed with the pitch or yellow pines. The wood, however, is less resinous and lighter than that of the southern yellow pines, and many manufacturers insist, with considerable reason, that it is so nearly like white pine that the word "white" should appear in the name. It is sold principally under the names of western pine, western white pine and California white pine. The cut reported for 1905 is 988,542,000 feet, given in Table 9. California leads with 363,932,000 feet, or 36.8 per cent.; Washington is second with 217,074,000 feet, or 22 per cent., and Montana third, with 101,998,000 feet, or 10.3 per cent. Then follow Oregon with 8.6 per cent. of the total, Idaho with 8.4 per cent., and Colorado with 4.9 per cent. Six other States cut 9 per cent. of the total.

TABLE 9.—*Cut of western yellow pine in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
California	110	363,932	36.8	Colorado	37	48,223	4.9
Washington	109	217,074	22.0	All others	60	88,720	9.0
Montana	19	101,998	10.3				
Oregon	44	84,955	8.6	Total	425	988,542	100.0
Idaho	46	83,640	8.4				

CYPRESS.

The cut of cypress by 468 mills in 1905 was 753,369,000 feet. Louisiana, as shown by Table 10, is by far the largest producer, with a cut of 487,504,000 feet, or 64.7 per cent. of the total. Relatively small amounts were cut in fourteen other States. Arkansas reported 8 per cent. of the total, Florida 7.4 per cent., Mississippi 7.2 per cent., South Carolina 3.5 per cent., North Carolina 2.7 per cent., and the remaining States combined 6.5 per cent.

TABLE 10.—*Cut of cypress in 1905.*

State.	Number of mills.	M feet	Per cent.	State.	Number of mills.	M feet.	Per cent.
Louisiana	73	487,504	64.7	North Carolina	52	20,423	2.7
Arkansas	98	60,252	8.0	All others	134	49,194	6.5
Florida	17	55,569	7.4				
Mississippi	74	54,211	7.2	Total	468	753,369	100.0
South Carolina	20	26,216	3.5				

The output of cypress has apparently not yet reached its maximum, as the Forest Service figures for 1905 are slightly greater than the Census figures for 1904, and over 50 per cent. larger than those of the Census for 1899.

REDWOOD.

The cut of redwood, 411,689,000 feet, reported by 55 mills, is given in Table 11. The area of production of this wood is very limited, but there is yet a comparatively large amount of stumpage and it is probable that the annual output will not fall below the present quantity for some time.

TABLE 11.—*Cut of redwood in 1905.*

State.	Number of mills.	M feet.	Per cent.
California	55	411,689	100.0

CEDAR.

Like spruce, "cedar" covers several species, the wood of which has similar properties. Cedar is used principally for poles, piles, posts, and shingles, and it is only in the State of Washington that any considerable quantity of it is cut into lumber. The amount of cedar lumber reported is given in Table 12. Of the total of 363,-900,000 feet, Washington produced 69.3 per cent., Maine 8.6 per cent., Oregon 7 per cent., Idaho 4.3 per cent., Michigan 3.4 per cent., Wisconsin 3.2 per cent., and twelve other States combined 4.2 per cent.

TABLE 12.—*Cut of cedar in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Washington	140	252,174	69.3	Wisconsin	18	11,591	3.2
Maine	52	31,267	8.6	All others	121	15,298	4.2
Oregon	65	25,428	7.0				
Idaho	8	15,560	4.3	Total	433	363,900	100.0
Michigan	29	12,582	3.4				

SUGAR PINE.

The cut of sugar pine by 63 mills in 1905 is given in Table 13. The range of merchantable sugar pine is practically restricted to the west side of the Sierra Nevadas and portions of the Coast range, and 97.6 per cent of the cut of 123,085,000 feet reported was in California. The cut of sugar pine in 1899, according to the Census, was only 53,558,000 feet, which indicates the rapid increase in output the last few years.

TABLE 13.—*Cut of sugar pine in 1905.*

State.	Number of mills.	M feet.	Per cent.
California	53	120,002	97.6
Oregon	10	3,083	2.4
Total	63	123,085	100.0

WESTERN WHITE PINE.

Western white pine is a true white pine, and very closely resembles the eastern white pine, both in the appearance of the tree and the properties of the wood. It is cut principally in a rather small territory covering portions of Montana, Idaho, and eastern Washington. So far as could be determined from the reports, the cut by

39 mills in these three States in 1905 was 115,678,000 feet, as shown in Table 14. It is quite certain, however, that the figures, particularly those for Washington, include considerable western yellow pine, which is frequently marketed under the name of white pine.

TABLE 14.—*Cut of western white pine in 1905.*

State.	Number of mills.	M feet.	Per cent.
Idaho	14	62,453	54.0
Washington	20	32,664	28.2
Montana	5	20,561	17.8
Total	39	115,678	100.0

OAK.

The cut of white and red oak reported for 1905 is given in Tables 15 and 16. No further separation into the various kinds of oak was practicable. Without question, a number of species were included under each head by the manufacturers, and quite probably in making out their reports they did not, in many cases, distinguish carefully between the white and red oaks. The oaks are among the most widely distributed hardwoods, and reports of oak lumber were received from thirty-five States. The total amount of white oak reported was 1,210,216,000 feet, of which West Virginia produced 12.9 per cent.; Kentucky, 12.7 per cent.; Ohio, 11.4 per cent.; Tennessee, 10.6 per cent., and Indiana, 10 per cent. The total amount of red oak reported was 623,553,000 feet, of which Tennessee cut 12.8 per cent., Arkansas, 10.8 per cent.; Kentucky, 9.3 per cent., and Indiana, 8.8 per cent.

While the Forest Service figures upon the output of oak in 1905 are incomplete, there is no doubt that the cut is decreasing because of the diminished supply of stumpage. The Census reports show a decrease of about 945,000,000 feet between 1899 and 1904.

TABLE 15.—*Cut of white oak in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
West Virginia	252	156,099	12.9	Mississippi	137	58,899	4.9
Kentucky	380	153,682	12.7	North Carolina	333	40,622	3.4
Ohio	467	137,268	11.4	Missouri	141	30,888	2.6
Tennessee	412	127,599	10.6	Alabama	90	20,302	1.7
Indiana	380	121,091	10.0	All others	1,142	106,744	8.5
Arkansas	270	100,502	8.3				
Pennsylvania	469	92,998	7.7	Total	4,726	1,210,216	100.0
Virginia	253	63,432	5.3				

TABLE 16.—*Cut of red oak in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Tennessee	367	79,793	12.8	Ohio	385	24,575	4.0
Arkansas	214	67,514	10,8	Virginia	167	23,298	3.8
Kentucky	277	58,056	9.3	Illinois	145	23,072	3.7
Indiana	375	54,725	8.8	Wisconsin	201	20,097	3.2
Mississippi	112	41,453	6.6	All others	1,207	123,128	19.8
North Carolina	261	41,411	6.6				
Pennsylvania	403	40,054	6.4	Total	4,263	623,553	100.0
West Virginia	149	26,378	4.2				

MAPLE.

The cut of maple reported by 2,765 mills in 1905 was 608,746,000 feet, as shown in Table 17. Michigan is by far the greatest producer of maple lumber, reporting 357,611,000 feet, or 58.8 per cent. of the total. Vermont cut 53,745,000 feet, or 8.9 per cent; Pennsylvania 48,883,000 feet, or 8 per cent.; New York 44,550,000 feet, or 7.3 per cent.; Wisconsin 40,425,000 feet, or 6.6 per cent.; Indiana 15,828,000 feet, or 2.6 per cent., and twenty other States combined, 47,704,000 feet, or 7.8 per cent. There has apparently been little change in the total output of maple for several years.

TABLE 17.—*Cut of maple in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Michigan	311	357,611	58.8	Indiana	298	15,828	2.6
Vermont	182	53,745	8.9	All others	1,002	47,704	7.8
Pennsylvania	326	48,883	8.0				
New York	421	44,550	7.3	Total	2,765	608,746	100,0
Wisconsin	225	40,425	6.6				

YELLOW POPLAR.

Table 18 shows the cut of yellow poplar reported by 2,115 manufacturers. This was 582,748,000 feet. Kentucky is the leading State, wtih 21 per cent. of the total, followed by West Virginia, with 19.2 per cent.; Tennessee, with 19 per cent.; Ohio, with 9.5 per cent.; North Carolina, with 8.3 per cent.; Virginia, with 7.1 per cent.; Alabama, with 6.5 per cent., and small amounts in nine other States. The Forest Service figures upon yellow poplar are incomplete, but probably the cut of this species is still decreasing. The Census figures show a heavy decrease between 1899 and 1904.

TABLE 18.—*Cut of yellow poplar in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Kentucky	309	122,485	21.0	Indiana	251	18,143	3.1
West Virginia	197	112,230	19.2	Mississippi	63	14,165	2.4
Tennessee	361	110,480	19.0	Georgia	78	11,128	1.9
Ohio	203	55,140	9.5	All others	148	11,753	2.0
North Carolina	274	48,122	8.3				
Virginia	156	41,294	7.1	Total	2,115	582,748	100.0
Alabama	75	37,808	6.5				

RED GUM.

In 1905, 898 mills cut 316,588,000 feet of red gum. The leading State, as shown by Table 19, is Arkansas, which cut 91,942,000 feet, or 29 per cent. of the total. Missouri comes second, with 71,948,000 feet, or 22.7 per cent.; and Mississippi third, with 47,320,000 feet, or 15 per cent. Then follow Tennessee with 11.7 per cent., Kentucky with 6.2 per cent., Indiana with 4.1 per cent., and Illinois with 3.2 per cent. Eleven other States combined cut 8.1 per cent. The cut of red gum has increased to some extent in the last few years, the Census figures on gum of all kinds in 1899 being 268,251,000 feet.

TABLE 19.—*Cut of red gum in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Arkansas	148	91,942	29.0	Indiana	94	12,858	4.1
Missouri	60	71,948	22.7	Illinois	51	10,072	3.2
Mississippi	95	47,320	15.0	All others	217	25,543	8.1
Tennessee	135	37,147	11.7				
Kentucky	121	19,758	6.2	Total	921	316,588	100.0

BASSWOOD.

In 1905, 258,390,000 feet of basswood was cut by 2,212 mills, as given in Table 20. Wisconsin produced nearly one-half the total, or 47.1 per cent. Michigan ranks second, with 18.1 per cent., followed by New York with 9.6 per cent., Pennsylvania with 4.9 per cent., and West Virginia with 4 per cent. Fifteen other States combined cut 16.3 per cent. The cut of basswood given by the Census of 1899 was 280,025,000 feet, but there has been some decrease since that time.

TABLE 20.—*Cut of basswood in 1905.*

State.	Number of mills.	M fect.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Wisconsin	300	121,857	47.1	West Virginia	94	10,251	4.0
Michigan	280	46,759	18.1	All others	957	42,243	16.3
New York	375	24,760	9.6				
Pennsylvania	206	12,520	4.9	Total	2,212	258,390	100.0

BIRCH.

In 1905, 1,327 mills cut 240,704,000 feet of birch. The figures for the leading States are given in Table 21. By far the largest amount was cut in Wisconsin, which reported 95,191,000 feet, or 39.5 per cent. of the total. Michigan cut 39,693,000 feet, or 16.5 per cent.; New York, 24,760,000 feet, or 10.3 per cent.; Pennsylvania, 23,852,000 feet, or 9.9 per cent.; Vermont, 21,750,000 feet, or 9 per cent.; Maine, 20,164,000 feet, or 8.4 per cent.; and nine other States, combined, 15.294,000 feet, or 6.4 per cent. of the total. There has been a relatively large increase in the cut of birch since 1899, for which year the Census reported 128,410,000 feet.

TABLE 21.—*Cut of birch in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Wisconsin	223	95,191	39.5	Maine	122	20,164	8.4
Michigan	191	39,693	16.5	All others	239	15,294	6.4
New York	225	24,760	10.3				
Pennsylvania	142	23,852	9.9	Total	1,327	240,704	100.0
Vermont	185	21,750	9.0				

COTTONWOOD.

The cut of cottonwood reported for 1905 by 422 mills was 236,000,000 feet. The leading State, as shown by Table 22, was Arkansas, with 90,920,000 feet, or 38.5 per cent of the total. Next in order came Mississippi, with 43,462,000 feet, or 18.4 per cent.; Louisiana, with 38,693,000, or 16.4 per cent.; Tennessee, with 28,683,000, or 12.2 per cent.; and small amounts in twenty-three other States, aggregating 34,242,000 feet, or 14.5 per cent. of the total. The cut of cottonwood in 1899, according to Census figures, was 401,437,000 feet, so it is probable that the cut in 1905 was considerably larger than is indicated by the reports to the Forest Service, though not equal to that of 1899.

TABLE 22.—*Cut of cottonwood in 1905.*

State.	Number of mills.	M feet.	Per cent.
Arkansas	66	90,920	38.5
Mississippi	30	43,462	18.4
Louisiana	15	38,693	16.4
Tennessee	16	28,683	12.2
All others	295	34,242	14.5
Total	422	236,000	100.0

ELM.

The cut of elm reported for 1905 was 227,038,000 feet, as shown by Table 23. Of this amount, Wisconsin cut 31 per cent.; Michigan, 25.2 per cent.; Indiana, 11 per cent.; Ohio, 9.9 per cent.; Arkansas, 4.1 per cent.; Missouri, 3.7 per cent.; and twenty-six other States, combined, 15.1 per cent. The cut of elm given by the Census for 1899 was 388,095,000 feet. There has been a falling off in the output since that time, but the cut in 1905 was probably somewhat larger than is indicated from the reports to the Forest Service.

TABLE 23.—*Cut of elm in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Wisconsin	254	70,327	31.0	Missouri	72	8,425	3.7
Michigan	254	57,305	25.2	All others	688	34,285	15.1
Indiana	299	24,911	11.0				
Ohio	316	22,464	9.9	Total	1,937	227,038	100.0
Arkansas	54	9,321	4.1				

CHESTNUT.

The cut of chestnut by 1,599 mills in 1905 was 224,413,000 feet. The figures for the leading States are given in Table 24. Pennsylvania heads the list, with 41,018,000 feet, or 18.3 per cent. of the total; Tennessee comes next, with 28,010,000 feet, or 12.5 per cent.; and then follow North Carolina, Connecticut and West Virginia, with over 25,000,000 feet each and approximately equal amounts. Kentucky reported 6.7 per cent. of the total; Virginia, 6.2 per cent.; Maryland, 5 per cent.; Massachusetts, 4.6 per cent., and thirteen other States combined, 12.6 per cent. The cut of chestnut in 1904 was 243,537,000 feet, according to the Census.

TABLE 24.—*Cut of chestnut in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Pennsylvania	397	41,018	18.3	Virginia	84	13,994	6.2
Tennessee	171	28,010	12.5	Maryland	31	11,228	5.0
North Carolina	117	25,628	11.4	Massachusetts	117	10,388	4.6
Connecticut	73	25,562	11.4	All others	321	28,312	12.6
West Virginia	141	25,256	11.3				
Kentucky	147	15,017	6.7	Total	1,599	224,413	100.0

BEECH.

The cut of beech reported for 1905 is given in Table 25. The output of 1,853 mills was 219,000,000 feet. Michigan is the leading State, with 59,896,000 feet, or 27.3 per cent. of the total. Pennsylvania comes next, with 53,494,000 feet, or 24.7 per cent.; and then Indiana, with 30,827,000 feet, or 14 per cent. Beech was reported from seventeen other States, but only relatively small amounts were cut outside of Michigan, Pennsylvania and Indiana, which furnished 66 per cent. of the total quantity reported. The Census gave no figures upon beech in 1899, so there is no basis for comparison.

TABLE 25.—*Cut of beech in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Michigan	192	59,896	27.3	Vermont	123	7,829	3.6
Pennsylvania	238	53,494	24.7	Kentucky	129	7,787	3.5
Indiana	285	30,827	14.0	All others	342	20,110	9.1
New York	275	24,760	11.3				
Ohio	269	14,297	6.5	Total	1,853	219,000	100.0

ASH.

In 1905, 159,634,000 feet of ash was cut by 2,653 mills. As shown by Table 26, Michigan was the leading State, with 26,141,000 feet, or 16.5 per cent. of the total. Next comes Wisconsin, with 14,588,000 feet, or 9.2 per cent., and then Indiana, Arkansas and Kentucky, with approximately 13,000,000 feet, or over 8 per cent. each. Relatively small amounts were reported from twenty-nine other States, but over half of the output came from the five States mentioned. The cut of ash in 1899, according to the Census, was 256,431,000 feet, but the output is decreasing, because of the scarcity of stumpage.

TABLE 26.—*Cut of ash in 1905.*

State.	Number of mills.	M feet.	Per cent.	State.	Number of mills.	M feet.	Per cent.
Michigan	253	26,141	16.5	South Carolina	12	7,460	4.7
Wisconsin	203	14,588	9.2	Pennsylvania	237	6,691	4.2
Indiana	279	13,340	8.4	Tennessee	154	5,819	3.6
Arkansas	88	13,034	8.2	All others	922	41,000	25.9
Kentucky	157	12,939	8.1				
Ohio	280	10,539	6.1	Total	2,653	159,634	100.0
Mississippi	68	8,083	5.1				

HICKORY.

The cut of hickory reported for 1905 by 1,829 mills was 95,803,000 feet. The figures for the principal States are given in Table 27. Indiana leads, with 15,138,000 feet, or 15.8 per cent.; followed by Arkansas, with 13,262,000 feet, or 13.8 per cent.; Kentucky, with 12,894,000 feet, or 13.4 per cent.; Tennessee, with 11,958,000 feet, or 12.5 per cent., and Ohio, with 11,054,000 feet, or 11.5 per cent. Mississippi reported 6.5 per cent. of the total, Illinois 5.6 per cent., Pennsylvania 5.4 per cent., Missouri 3.6 per cent., West Virginia 2.4 per cent. Twenty other States combined reported 9.5 per cent. The total cut of hickory in 1905 reported to the Forest Service is practically the same as that given by the Census for 1899, but there is no doubt that these figures are considerably below the actual annual consumption of hickory. A considerable amount of hickory, particularly spoke material, is sold by the piece, and consequently was not reported as lumber. The members of the National Hickory Association estimate their annual requirements as equivalent to 250,000,000 board feet.

TABLE 27.—*Cut of hickory in 1905.*

State.	Number of mills.	M feet	Per cent.	State.	Number of mills.	M feet.	Per cent.
Indiana	319	15,138	15.8	Pennsylvania	188	5,146	5.4
Arkansas	181	13,262	13.8	Missouri	68	3,430	3.6
Kentucky	148	12,894	13.4	West Virginia	74	2,310	2.4
Tennessee	148	11,958	12.5	All others	308	9,064	9.5
Ohio	352	11,054	11.5				
Mississippi	40	6,239	6.5	Total	1,829	95,803	100.0
Illinois	103	5,308	5.6				

OTHER KINDS.

Several kinds of lumber which are cut only in relatively small amounts, and the States in which they are chiefly produced, are given in Table 28. These are: Larch, 76,173,000 feet; tamarack, 64,463,000 feet; white fir, 52,725,000 feet; tupelo, 35,794,000 feet; balsam, 35,506,000 feet; and walnut, 29,851,000 feet. While these woods are of minor importance, their output, with the exception of walnut, has increased strongly since 1899. The cut of larch and tamarack combined for that year is given by the Census as only 49,802,000 feet, while no figures at all are given for balsam and tupelo.

TABLE 28.—*Cut of minor species in 1905.*

Kind.	M feet.	States mostly cut in.
Larch	76,173	Montana, Washington, Idaho, Oregon.
Tamarack	64,463	Wisconsin, Michigan, Minnesota.
White fir	52,725	California, Washington, Oregon.
Tupelo	35,794	Virginia, Louisiana, Alabama, North Carolina, etc.
Balsam	35,506	Maine, Vermont, New York, etc.
Walnut	29,851	Indiana, Ohio, Illinois, Missouri, Kentucky, Tennessee, etc.

PRODUCTION BY STATES.

The production of lumber in 1905 by 11,666 mills is given by States and species in Table 29. The following States led in the production of the kinds of timber specified:

Arkansas: Red gum and cottonwood.
California: Western yellow pine and redwood.
Idaho: Western white pine.
Indiana: Hickory and walnut.
Kentucky: Yellow poplar.
Louisiana: Yellow pine and cypress.
Maine: Spruce and balsam.
Michigan: Maple, beech and ash.
Minnesota: White pine.
Montana: Larch.
Pennsylvania: Hemlock and chestnut.
Tennessee: Red oak.
Washington: Douglas fir and cedar.
West Virginia: White oak.
Wisconsin: Basswood, birch, elm and tamarack.

SHINGLES.

The cut of shingles in 1905 by 2,547 mills is given in Table 30. The total number reported was 15,340,909,000, of which western cedar furnished 9,595,245,000, or 62.5 per cent; cypress 1,514,-478,000, or 9.9 per cent.; eastern cedar 1,313,297,000, or 8.6 per cent.; Douglas fir 911,173,000, or 5.9 per cent. The cut of redwood shingles reported was 483,887,000, or 3.1 per cent. of the total; of yellow pine 459,472,000, or 3 per cent.; of white and Norway pine 382,742,000, or 2.5 per cent.; and of hemlock 135,020,000, or 0.9 per cent. The shingles cut of other species than those mentioned amounted to 3.6 per cent. of the total.

The total number of shingles cut in 1899, according to the Census, was 11,947,620,000. Most of the increase in cut in 1905 consists of western red cedar.

TABLE 30.—*Cut of shingles in 1905.*

Kind.	Number of thousands.	Per cent.	State.	Number of mills.	Number of thousands.	Per cent.
Western cedar	9,595,245	62.5	Washington	515	10,509,914	68.6
Cypress	1,514,478	9.9	Michigan	153	875,051	5.7
Eastern cedar	1,313,297	8.6	Louisiana	62	743,398	4.8
Douglas fir	911,173	5.9	California	71	547,863	3.6
Redwood	483,887	3.1	Wisconsin	112	417,046	2.7
Yellow pine	459,472	3.0	Maine	214	312,497	2.0
White and Norway pine	382,742	2.5	Arkansas	47	302,135	2.0
Hemlock	135,020	.9	Alabama	50	285,080	1.8
All others	545,595	3.6	Minnesota	68	193,738	1.3
			Georgia	112	177,986	1.2
			Florida	40	154,524	1.0
			All others	1,043	821,677	5.3
Total	15,340,909	100.0	Total	2,547	15,340,909	100.0

Washington is far in the lead as a shingle-producing State, since it cut 68.6 per cent. of the total number reported. This is because most of both the western and cedar and the Douglas fir shingles come from this State. Michigan comes next in order, with 5.7 per cent., consisting mostly of cedar; then Louisiana, with 4.8 per cent., made up principally of cypress. The California shingles are mostly redwood, those of Wisconsin and Maine cedar, those of Minnesota northern pine, and those of the Southern States yellow pine and cypress.

LATH.

The total cut of lath reported for 1905 by 1,801 mills was 3,111,-157,000, as shown in Table 31. White and Norway pine lead with 872,599,000, or 28.1 per cent. of the total. Douglas fir ranks second, with 584,884,000, or 18.8 per cent.; hemlock third, with 430,014,000,

or 13.8 per cent.; and yellow pine fourth, with 407,742,000, or 13.1 per cent. Practically three-fourths of the lath were of these four species. Spruce is credited with 260,039,000, or 8.4 per cent. of the total; cypress with 155,825,000, or 5 per cent. Lath of other kinds and those which could not be determined are given under the head "Mixt," the number being 400,054,000, or 12.8 per cent. of the total. The Census reported a production of 2,501,314,000 lath of all kinds in 1899.

TABLE 31.—*Cut of lath in 1905.*

Kind.	Number of thousands.	Per cent.	State.	Number of mills.	Number of thousands.	Per cent.
White and Norway pine	872,599	28.1	Washington	97	559,813	18.0
Douglas fir	584,884	18.8	Minnesota	80	422,025	13.3
Hemlock	430,014	13.8	Wisconsin	195	328,905	10.6
Yellow pine	407,742	13.1	Louisiana	56	259,259	8.3
Spruce	260,039	8.4	Maine	121	255,482	8.2
Cypress	155,825	5.0	Michigan	109	221,386	7.2
Mixt	400,054	12.8	Pennsylvania	211	219,143	7.0
			Oregon	34	116,456	3.8
			All others	898	728,688	23.6
Total	3,111,157	100.0	Total	1,801	3,111,157	100.0

The leading States in the production of lath are also given, in order, in Table 31, their relative importance being due to one or more of the species mentioned in the preceding paragraph. Washington comes first, with 18 per cent. of the total reported, followed by Minnesota, with 13.3 per cent., Wisconsin with 10.6 per cent., Louisiana with 8.3 per cent., Maine with 8.2 per cent., Michigan with 7.2 per cent., Pennsylvania with 7 per cent., and Oregon with 3.8 per cent. These eight States produced over three-fourths of the total number of lath reported.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 30, 1906.

U. S. DEPARTMENT OF AGRICULTURE.
Forest Service—Circular 115.
GIFFORD PINCHOT, FORESTER.

Second Progress Report on the Strength of Structural Timber

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INTRODUCTION.

The information contained in this circular was secured by systematic tests, carried on for four years, by the methods given in Circular 38, entitled "Instructions to Engineers of Timber Tests," and it supplements the results published in Circular 32 (Bureau of Forestry), "First Progress Report on the Strength of Structural Timber." Loblolly pine, longleaf pine, tamarack, and Norway pine, the principal structural timbers of the eastern United States, and Douglas fir and western hemlock of the Pacific coast were the woods tested.

The tests were made at the various testing laboratories of the Forest Service, located at Washington, D. C.; Charleston, S. C.; Purdue University, Lafayette, Ind.; the University of California, Berkeley, Cal.; the University of Oregon, Eugene, Ore.; the University of Washington, Seattle, Wash., and the Yale Forest School, New Haven, Conn.

There were two general classes of tests: (*a*) Tests on large beams, for studying the relations between strength, defects and degree of seasoning, and for determining moduli for design; (*b*) tests on small pieces cut from the uninjured parts of the tested beams. The latter, classed as minor tests, include bending, compression parallel to grain and at right angles to grain, and shearing. Minor tests are used to study the effects of moisture, rate of growth, and other factors. In such studies defects must, as far as possible, be eliminated.

Tests of class *a* were made upon large sticks, such as bridge stringers and other structural timbers having such knots, crooked grain, and other defects as are found in market material.

The attention of shippers is called to the weights of the different materials given in the tables. The weight of air-dry material, as found upon the market, varies considerably, but as a rule it will

exceed the oven-dry weight given in the tables by from 15 to 30 per cent., according to size and species. The oven-dry weight is obtained from the weight and from the volume of measurements of the timber at the time of test, in conjunction with subsequent moisture determinations. The shrinkage of the timber is not taken into account. This is variable and at present is not accurately known. It is estimated that air-dry timber has lost about 5 per cent. of its green volume.

The actual weight of the wood at the time it was tested may be computed from the oven-dry weight and moisture per cent. Thus, a dry weight of 29.4 pounds per cubic foot, at a moisture per cent. of 19.4, gives a weight of 35.1 pounds per cubic foot at the time of the test. The measurements of volume were, in most cases, those of surfaced lumber.

The origin of the sticks and their stage of seasoning are carefully described. Photographs were taken and drawings made locating knots and showing the amount of heart, sap, wane, etc. The sticks were graded by an experienced lumber inspector.

The tables give the average, maximum, and minimum values.

Results of tests on individual sticks will be published in connection with special reports.

SUMMARY.

A digest of the results of bending tests on large sticks given in the tables is shown in Table 1, which indicates the weight, strength, and stiffness of beams, such as are found on the market and used by engineers. More detailed information is given in the various other tables. The modulus of rupture represents fairly well the strength of the timber; the modulus of elasticity represents its stiffness. The strength of small, clear, green sticks cut from these beams is found in Table 11.

It should be noted that the strength values of wood usually quoted in handbooks are based on small, clear, well-seasoned sticks, the strength of which largely exceeds that of large structural timber.

TABLE 1.—*Summary of the average bending strength of structural timber.*

Reference No.	Species and locality of growth.	Grade.	Condition.	Number of tests.	Moisture per cent.	Weight per cubic foot.		Modulus of rupture.	Modulus of elasticity.
						As tested.	Oven dry.		
	LOBLOLLY PINE.					*Lbs.*	*Lbs.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*
1	South Carolina..	Square edge.....	Green..........	42	48.0	46.2	31.2	$5,580_{7}$	1,426
	LONGLEAF PINE.								
2	South Carolina.. and Georgia.	Merchantable...	Partially air dry.	44	26.1	49.8	39.5	$7,772_{15}$	1,690
	DOUGLAS FIR.								
3	Oregon and Washington.	All grades......	Partially air dry.	216	22.1	33.8	27.7	$6,975_{54}$	1,600
4	....do..........	Select and merchantable.	....do..........	164	22.0	33.9	27.7	$7,500_{43}$	1,636
5	Oregon.........	All grades......	Green..........	135	30.9	38.4	29.4	$6,140_{26}$	1,526
6	....do..........	Select and merchantable.	....do..........	103	31.3	38.6	29.4	$6,430_{24}$	1,585
	WESTERN HEMLOCK.								
7	Oregon and Washington.	All grades......	Partially air dry.	64	27.8	33.2	26.0	$5,992_{12}$	1,351
8	Washington.....	....do..........	Green..........	30	36.2	38.8	28.5	$5,783_{16}$	1,475
	TAMARACK.								
9	Minnesota......	Merchantable...	Green..........	30	50.6	45.2	30.1	$4,562_{4}$	1,219
	NORWAY PINE.								
10	Minnesota......	Merchantable...	Green..........	49	47.8	37.4	25.4	$3,975_{7}$	1,189

NOTE.—Figures written as subscripts to the figures for modulus of rupture indicate the number of sticks failing in longitudinal shear.

The moisture condition of the beams varied somewhat between the different species given in Table 1. The moisture content of green timber also varies with the species—for instance, the maximum is about 37 per cent. of the dry weight in the case of Douglas fir heartwood and as high as 100 per cent. in the case of loblolly pine sapwood, so that the same moisture per cent. in these two woods does not represent an equal degree of seasoning. Again, Douglas fir seasons more rapidly in the dry climate of California than does loblolly pine in the moist climate of the Atlantic coast.

It is surprising how much moisture is found in well-seasoned timber. Sticks of longleaf pine 10 by 12 inches in cross section after drying in a lumber yard at Washington, D. C., for one year contained 35 per cent. of moisture, and sticks of loblolly pine from Virginia, 8 by 8 inches in cross section, after drying in the same

place for two years and becoming almost black on the surface, contained 34 per cent. of moisture.

In small sticks the strength begins to increase after the moisture has been reduced to about 26 per cent.* The laws expressing the relation of strength and moisture in the cases of small sticks do not, however, necessarily apply to large sticks. Timbers of commercial size develop checks and other defects while seasoning, and these partially offset the increase in strength due to drying. However, in the case of select sticks the actual strength was in some cases increased from 10 to 25 per cent. by one year of careful seasoning.

LOBLOLLY PINE.

Loblolly pine has not only a wide range of structural merit, but also a wide distribution. It occurs in a belt along the Atlantic coast and the Gulf of Mexico, from Virginia to eastern Texas, extending inland from 50 to 300 miles.

Under the name of Virginia pine the timber cut in the northern portion of this belt is generally found on the markets in small sticks, 8 by 8 inches or 10 by 10 inches in cross section, almost entirely sapwood and of so rapid a growth that sometimes only four rings occur in 3 inches. This is second-growth timber, usually very knotty and of an inferior grade. The same species is also marketed under the name of North Carolina pine, and in that case it is generally forest-grown timber of large size, with a large proportion of heartwood, fairly free from knots, and possessing a high order of structural value.

In the forest loblolly pine is prolific, grows vigorously, and holds its place in competition with other species. It is the principal tree in the operations of those lumber companies in the Southern States which look upon their forest holdings as part of their capital and reap successive crops from them by conservative forest management. It is therefore a timber which engineers and architects may expect to find on the market for an indefinite period. The chief objection to it is that being largely sapwood it decays rapidly when exposed. Because of its open grain, however, it is a wood which may be treated very successfully with preservatives.

Table 2, reference numbers 1-5, gives the results of bending tests on loblolly pine obtained from a mill at Charleston, S. C., and on the market at Washington, D. C.

The loblolly pine listed in the table, under reference numbers 1,

*See Bulletin No. 70 Forest Service, "Effect of Moisture on the Strength and Stiffness of Wood."

2 and 3, was "North Carolina pine," cut from the holdings of the E. P. Burton Lumber Co., near Charleston, S. C. It is a timber that generally shows sapwood on all four faces, and is on this account of a "standard" or "square edge" grade according to the Standard Inspection Rules (1902) of the Georgia Sawmill Association. These rules have been revised since this timber was graded, so as to allow more sap in the merchantable grade. A number of sticks classed as "square edge" in the table would now be graded as merchantable. The timber is good structural material, such as is used in warehouses, mills, and other structures in which the conditions do not demand longleaf pine.

Some of the bending tests (Table 2) were made with the load applied at the center of the span, and the remainder with the load applied at points one-third of the span from each end. The modulus of rupture of the green North Carolina pine beams (Table 2, reference number 1) is 5,580 pounds per square inch, and the modulus of elasticity 1,426,000 pounds per square inch. In the case of the partially air-dried beams containing from 25 to 30 per cent. of moisture (reference number 2) these values are 5,650 pounds per square inch, and 1,435,000 pounds per square inch, respectively. The oven-dry weight of the timber in both of these groups is 31.2 pounds per cubic foot. The moisture per cent. was 27.7 for the partially air-dried and 48 for the green material. Diagrams I and II show the distribution of moisture throughout the cross section of beams under different conditions of seasoning.

In the case of the partially air-dried beams containing less than 25 per cent. moisture (reference number 3), the modulus of rupture is 5,690 pounds per square inch, and the modulus of elasticity 1,340,000 pounds per square inch. The average moisture was 21 per cent., and the oven-dry weight 31.2 pounds per cubic foot. Reference numbers 1 to 3 show that the seasoning ordinarily undergone by large loblolly pine beams has little, if any, effect upon their strength.

The 8 by 8 inch partially air-dried Virginia pine (Table 2, reference number 4) was cut in Stafford County, Va., and had been drying in the yard for two years. This material has a modulus of rupture of 5,180 pounds per square inch, a modulus of elasticity of 1,180,000 pounds per square inch, at a moisture per cent. of 22.4, and an oven-dry weight of 28.8 pounds per cubic foot.

The 8 by 8 inch green Virginia pine (reference number 5), was cut about March, 1903, and was tested about one month after cutting. The timber was "sap stained," but it has been shown that

this staining, or "bluing," does not impair the strength of the wood. The modulus of rupture of these beams is 3,490 pounds per square inch, the modulus of elasticity 744,000 pounds per square inch, the oven-dry weight 26.9 pounds per cubic foot, and the weight as tested 43.7 pounds per cubic foot.

Table 11, reference number 1, shows a comparison of the strength values of small sticks and large parent beams of loblolly pine. The ratio of the strength values of the large beams to the small beams is 0.77 for the fiber stress at elastic limit, 0.71 for the modulus of rupture, and 0.99 for the modulus of elasticity. Table 12, reference numbers 1 and 2, gives the results of tests in compression parallel to grain. The crushing strength of North Carolina pine, partially air dry, and green, is 4,250 and 3,510 pounds per square inch, respectively. This is higher than the crushing strength of the Virginia pine, which is 2,950 pounds per square inch when partially air dry, and 2,140 pounds per square inch when green.

Table 13, reference number 1, gives the results of tests on loblolly pine in compression at right angles to grain. The average compressive strength at the elastic limit at right angles to grain is 469 pounds per square inch. The material was green, containing 57.1 per cent moisture.

Table 14, reference number 1, gives the results of shearing tests parallel to grain on small blocks. The shearing strength is 630 pounds per square inch, in material containing 83.2 per cent moisture.

MOISTURE DISTRIBUTION.

The moisture distribution in the cross section of North Carolina pine beams was determined by cutting sections 1 inch in thickness from near the center of the sticks and dividing the sections into nine parts in the directions shown in Diagrams I and II. The figures in the various parts of the sections show the percentage of moisture.

← 14 inches →

← 8 inches →			
	32.6 per cent.	31.9 per cent.	29.3 per cent.
	30.7 per cent.	39.6 per cent.	33.2 per cent.
	28.6 per cent.	30.9 per cent.	29 per cent.

Average 31.7 per cent.

DIAGRAM I.—Distribution of moisture in cross section midway of the length of North Carolina loblolly pine beams. Average of 10 sections taken from sticks 8 by 14 inches by 10 feet. The timber was air dried from 2 to 5 months.

The distribution of moisture throughout the cross section was also determined on a set of disks cut from beams under three conditions of seasoning—green, air-dry, and kiln-dry. Diagram II shows the distribution in the three cases, sapwood being denoted by crosshatchings.

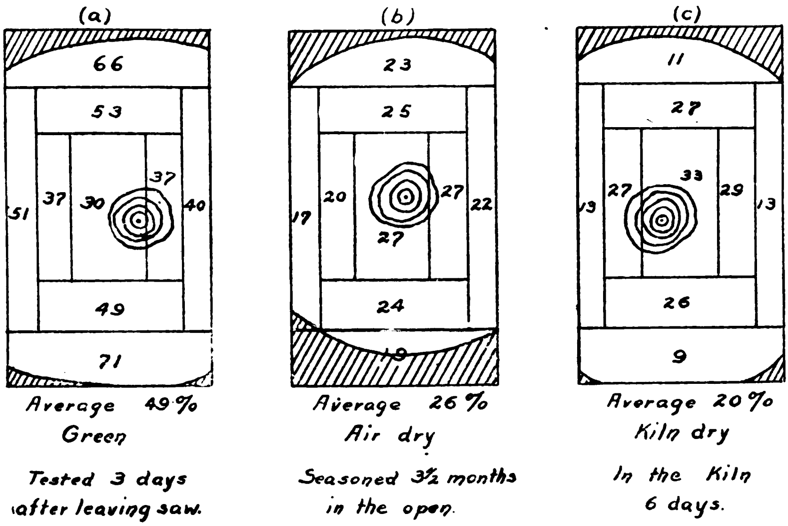


DIAGRAM II.—Distribution of moisture in cross section midway of the length of North Carolina pine beams.

(*a*) Average of 10 sections.
(*b*) Average of 4 sections.
(*c*) Average of 4 sections.
Sticks 8 by 16 inches in section.

In green timber that has been submerged in water for some time the moisture per cent near the surface is nearly twice that in the central part. In the air-dried sticks the drying did not penetrate to the central part at all. Section *c* was dried more quickly than the others, and the variation in the different parts is consequently greater. The sections used in both *b* and *c* were cut from sticks which were badly checked by too rapid seasoning. Along the beam variation in moisture was determined from sections cut from all beams at the quarter and center points, as shown in Tables 9 and 10. The moisture in the sections from the same beam varies so little that the longitudinal moisture distribution in 16-foot sticks may be taken as practically uniform, except at the ends and in cases where the percentage of sapwood varies greatly throughout the length of the beam.

In Table 3 the effect of seasoning on the strength of large beams

is well shown. Three sets of green North Carolina pine beams were dried in the open air in sunlight, in a kiln, and in a shed, respectively. The wood in the outer portion of the two sets of beams listed first was no doubt stronger than in the green condition. The beams failed in horizontal shear, however, before the added strength could be brought out, because of the presence of checks and shakes. A marked increase in strength was shown by the beams of select material that were carefully dried in a shed. The modulus of rupture of green material similar to that in Table 3 is 5,580 pounds per square inch. (Table 2, reference number 1.)

The actual shearing strength of loblolly pine, as determined by tests made on small blocks, is 630 pounds per square inch. (Table 14, reference number 1.) Out of 42 sticks, from 6 by 7 inches to 8 by 16 inches, tested on spans of from 10 to 16 feet (Table 8, reference number 1), 7 failed in horizontal shear at an average stress of 339 pounds per square inch. Since the actual shearing strength of the wood fiber was 630 pounds per square inch, and the longitudinal shearing stress in the beams at failure 339 pounds per square inch, this shows that only a little over half of the horizontal section of the beams was in a condition to resist shear. The fact that engineers should design beams with reference to the unit stresses deduced from tests of green timber and to horizontal shear was pointed out in Circular 32.

Two sections were cut from all sticks tested in bending, and their average moisture content was used as the moisture content of the beam. Tables 9 and 10 show a comparison of the moisture in sections cut from the same beam at the center and at one of the quarter points. Longleaf pine and loblolly pine are both included in Table 10.

In a stick in which the ratio of sap to heart varies throughout the length the distribution of moisture along the beam is likely to vary also. If the stick has been wet a short time before the determinations are made, it will be found that the sections containing the most sapwood will contain the greatest amounts of moisture, because the sapwood absorbs water much more readily than the heartwood. On the other hand, if the stick has been in the water long enough for both heartwood and sapwood to become saturated, and is then dried, the sections containing the most heartwood will have the highest percentage of moisture, because sapwood dries out more readily than heartwood. The sticks in Table 10 were partly green and partly air-dry. This accounts for the wide variation of moisture in the different sticks.

EFFECT OF KNOTS.

A series of tests was made to determine the weakening effect of knots. The timber used was North Carolina pine obtained from the E. P. Burton Lumber Company, Charleston, S. C. This was tested at the mill. The logs went to the saw directly from the millpond, and the sticks were tested within a few days after leaving the saw. The logs were sawed, in the presence of the testing engineer, so as to include knots of various positions, sizes, and conditions. Ninety-three such sticks, 5 by 12 inches in cross section, were then tested in bending on a 15-foot span. Thirty-four sticks were loaded at the center, and the remainder tested under "third-point" loading. Tables 4 and 5 give the results of these tests.

After a few trials a method of analysis was devised in which the area of the faces of the sticks (vertical in the tests) was divided to indicate part volumes of the stick as shown above the tables. Volume 1 is the middle half of the stick one-quarter of the height up from the bottom. A knot, wavy grain, or defect occurring in this volume throws the stick into group 1. Volume 2 is the middle half of the stick one-quarter of the height down from the top. Sticks having defects in volume 2 and not in volume 1 are put in group 2. Sticks with defects outside of volumes 1 and 2 go to group 3. In Table 4, for beams loaded at third points, the unit strength values and the relative strength for the different groups are given. The modulus of rupture for groups 1 and 2 is about 75 per cent of that in group 3. Minor test pieces free from defects were cut from the main beams in order to obtain the relative strength of these small clear pieces in the different groups.

It will be noted that the strength of the small test pieces cut from the sticks in group 3 was greater than that of those in groups 1 and 2. All of the sticks were green, and the results are therefore on the same moisture basis. This indicates that part of the variation in the strength of the 3 groups of large sticks is due to inherent differences in the wood fiber. The selection of such sticks as those in group 3 (sticks without defects in volumes 1 and 2) usually would involve close, firm growth, because of the fact that rapid growth and knots generally occur together. Table 5 gives the strength of the groups for sticks loaded at the center point of the span.

A series of tests was also made to determine the weakening effect of knots on Douglas fir. In these tests volume 1 and volume 2 included the middle two-thirds of the stick one-quarter of the height from the edges. The beams were loaded at the center. From Table

6, giving the results of these tests, it is seen that the effect is about the same.

The following is a general rule for classifying sticks with reference to knots, wavy grain, and other defects.

Class 1.—Sticks clear in middle half, one-quarter of height from top and bottom (not necessarily clear in remaining volume).

Class 2.—Sticks having defects in middle half, one-quarter of height from top or bottom.

The strength of sticks in class 2 may be taken as 75 per cent of the strength of sticks in class 1.

EFFECT OF SEASONING.

It appears that the strength of large sticks changes very little for the range of moisture usually met with in practice. Small pieces when kiln-dried increase in strength as much as 300 per cent, but large beams can not be dried out to the same extent. Moreover, the drying process often produces checks and ring shakes, the weakening effects of which more than counterbalance any gain in strength due to seasoning. (See Table 2, reference numbers 1-3).

LONGLEAF PINE.

Longleaf pine has been for a long time the standard construction timber, not only on account of its strength, hardness, and durability, but also on account of the good lengths of heartwood that can be obtained free from knots.

Longleaf pine timber has been very extensively tested, not only in small sticks, but, more rarely, in large sticks as well. In the markets at present any heart pine, whether longleaf, shortleaf, or loblolly, which shows a close-ringed, hard texture, is sold under the name of longleaf pine, while the wider ringed, more rapid, and sappy growth is sold as shortleaf pine. The names "Georgia pine" and "Alabama pine" are often used to designate timber coming from the tracts of longleaf pine in those States.

The tests given in Table 2 represent longleaf pine of an excellent merchantable quality. The timber from South Carolina (reference number 6), was obtained in the Philadelphia market and had been cut about two years when tested. That from Georgia was purchased at New Haven, Conn., and had been on the market about six months. It was of better quality than that ordinarily found in the market as "merchantable" stock.

The modulus of rupture of South Carolina longleaf (reference number 6), is 7,160 pounds per square inch, and the modulus of

elasticity 1,560,000 pounds per square inch. The strength values, which are higher in the case of the Georgia timber, are 8,384 and 1,820,000 pounds per square inch, respectively. The moisture is about the same in both cases, but the rate of growth is somewhat less in the Georgia material. The average dry weight per cubic foot in the Georgia pine is 42.9 pounds as against 36.2 pounds for the South Carolina material. Table 11 (reference number 2) gives the strength of small clear pieces cut from the main sticks. The strength ratio of the large to the small sticks is 0.77 for the fiber stress at elastic limit, 0.79 for the modulus of rupture, and 1.01 for the modulus of elasticity.

The crushing strength parallel to grain for longleaf pine is 4,800 pounds per square inch (Table 12, reference number 5). The material contained 26.3 per cent moisture.

The compressive strength at elastic limit at right angles to grain is 572 pounds per square inch (Table 13, reference number 2).

The shearing strength parallel to grain for small specimens is 973 pounds per square inch (Table 14, reference number 2).

In Diagram III is shown the moisture distribution in the cross section of beams air-dried for two years.

←16 inches→

↑	21.5	17.2	19.5
8 inches	17.0	25.7	17.4
↓	17.8	16.3	18.1

Average 23.3 per cent.

DIAGRAM III.—Average of two sections of longleaf pine taken from sticks 12 by 12 inches and 8 by 16 inches by 16 feet long, air-dried two years. Average per cent. of sapwood 2.

From this diagram it may be seen that in beams air-dried for two years the drying did not penetrate to the center. It is very noticeable in the tests that longleaf pine tends to check upon drying out and to fail by longitudinal shear. In the case of the sticks in Table 8, reference number 3, 9 out of the 22 failed by longitudinal shear. The longitudinal shearing stress in the beams that failed in that manner was 335 pounds per square inch. The shearing strength of longleaf pine, as determined from small blocks, is 973 pounds per square inch (Table 14, references number 2). From this it will be seen that the beams were so weakened by checks, shakes, etc., due to seasoning, that only about one-third of the longitudinal section was left in a condition to resist shear.

TAMARACK.

Tamarack reaches its best development north of the United States boundary, in Canada. It extends southward to northern Pennsylvania, northern Indiana and Illinois, and central Minnesota. In the United States tamarack occurs in pure stands in cold, deep swamps, which it often clothes with forests of densely crowded trees rarely more than 40 or 50 feet in height. The maximum height of 60 feet and the maximum diameter of 20 inches are rarely attained in the United States. The trunk is straight and tapers rather rapidly; it clears itself readily of branches even when growing in fairly open stands. Tamarack lumber is cut principally in Wisconsin, Michigan, and Minnesota.

The results of bending tests on green tamarack are contained in Table 2, reference number 8. The modulus of rupture is 4,562 pounds per square inch, and the modulus of elasticity 1,219,000 pounds per square inch. The oven-dry weight is 30.1 pounds per cubic foot, and the moisture was 50.6 per cent.

NORWAY PINE.

Norway pine reaches its best development in the United States in the northern parts of Michigan, Wisconsin, and Minnesota, usually forming groves of a few hundred acres in extent on light, sandy loam or dry, rocky ridges. It ordinarily reaches a height of 75 feet and a diameter of 30 inches, though sometimes twice these dimensions are attained. The trunk is straight and clear of branches. The wood is rather close-grained, is pale red when air-dried, and has a thin ring of sapwood. Norway pine is cut and sold with white pine in the Lake States under the name of northern pine. It probably makes up about one-third of the present pine cut in this region.

Table 2, reference number 9, contains the results of bending tests on green Norway pine. The modulus of rupture is 3,975 pounds per square inch, and the modulus of elasticity 1,189,000 pounds per square inch. The oven-dry weight is 25.4 pounds per cubic foot. The moisture in the green material was 47.8 per cent.

DOUGLAS FIR.

The Douglas fir of the Pacific coast is also known commercially as yellow fir, red fir, Oregon pine, and Douglas spruce. The name Douglas fir is, however, gradually becoming established. A single species, *Pseudotsuga taxifolia*, furnishes the timber. Its range ex-

tends from Lower California to central British Columbia, and from the Pacific Ocean to the Rocky Mountains. This timber reaches its best development in western Washington and Oregon, between the summit of the Cascade Mountains and the Pacific. Almost pure forests are found here, which frequently yield from 50,000 to 100,000 board feet per acre. In these regions the tree will average 5 to 6 feet in diameter at the butt, with a height up to 300 feet. The trunk is straight and readily clears itself of branches.

It is possible, therefore, to obtain exceptionally large and long pieces for structural purposes. Sticks 24 inches square and up to 100 feet long are regularly listed and obtainable in the merchantable grades. The possibility of procuring such large pieces, combined with the exceptional strength and stiffness of the material compared with its weight, renders Douglas fir an ideal structural timber. It is almost entirely heartwood, and is fairly durable when exposed to the weather.

Small trees varying from 1 to 3 feet in diameter are unsurpassed for spars, owing to the straightness of the trunk, the small taper, and the great length obtainable. Douglas fir is almost exclusively used on the Pacific coast for piling for docks and foundations for heavy structures in soft ground. The standard dimensions for this purpose are 12 inches in diameter and from 60 to 70 feet long.

In the green logs from mature trees the sapwood forms a narrow, light-colored ring, extending usually not more than 2 inches beneath the bark. In the seasoned timber, however, it can seldom be distinguished by color. Although the grading rules allow sapwood only on the corners for the merchantable grades, lumbermen have no difficulty in meeting the requirements.

The color of the wood of Douglas fir ranges from a light yellow to a pronounced red; the grain varies from as few as 4 or 5 rings per inch, in small trees or in heartwood, to a fine, even grain with upward of 40 rings per inch. The rings are usually strongly marked, the summer wood being very dense and dark, and the spring wood much softer. The wide-ringed wood is somewhat spongy. Owing to the marked difference in the texture of the alternate rings and to the long, regular fiber, the wood splits easily, especially when dry. For the same reason it is particularly pleasing for inside finish, paneling, etc., when slash-sawed, for the porous spring wood readily absorbs wood stains, whereas the dense summer rings are little affected, so that any desired shade may be secured.

Douglas fir is cut into every form of lumber, from rough timbers, used in the framing of heavy structures of all kinds where strength

and durability are required, to the fine-grained, clear stock for flooring.

The mechanical tests were made upon market products. The sticks were graded by an experienced lumber inspector, according to the Pacific coast standard of 1900, and, as is usual in the timber tests of the Forest Service, the grading of the inspector was found to correspond closely to the average results of the mechanical tests. The sizes given in Table 7, reference numbers 1 to 8, are those generally used in railroad work for bridge, trestle, and car construction.

It is evident from Table 7 that Douglas fir is of varied quality and that specifications need to be drawn somewhat more carefully than in the case of longleaf pine in order to exclude the wider-ringed quick growth and knotty sticks.

From an average of all grades and sizes in Table 7, reference number 4, it appears that the modulus of rupture of partially air-dried beams is 6,975 pounds per square inch, the modulus of elasticity 1,600,000 pounds per square inch, and the oven-dry weight per cubic foot 27.7 pounds, or 33.8 pounds per cubic foot as tested in a partially dry condition. The average rate of growth was about 15 rings per inch—that is to say, the tree added 1 inch to its radius, or 2 inches to its diameter, in fifteen years.

In green beams an average of all grades and sizes (Table 7, reference number 8) shows a modulus of rupture of 6,140 pounds per square inch, a modulus of elasticity of 1,526,000 pounds per square inch, and an oven-dry weight per cubic foot of 29.4, or 38.4 pounds per cubic foot as tested in a green condition. The rate of growth of the green beams was 10.8 rings per inch.

Table 11, reference number 3, gives the comparative bending strength of large and small sticks. The ratio is 0.77 for fiber stress at elastic limit, 0.71 for modulus of rupture, and 0.99 for modulus of elasticity, in the case of partially air-dried beams, and 0.71, 0.72, and 0.87, respectively, in the case of green beams (reference number 4).

Table 12, reference number 6, gives the crushing strength parallel to grain for Douglas fir as 4,406 pounds per square inch for partially air-dried timber. In the case of green timber (reference number 7) the crushing strength is 3,590 pounds per square inch.

Table 13, reference number 3, shows the compressive strength at elastic limit, at right angles to the grain, to be 651 pounds per square inch.

Table 14, reference number 3, gives the shearing strength parallel to grain of small blocks of partially air-dry Douglas fir as 770 pounds per square inch.

Table 8, reference number 4, shows that out of 216 tests on partially air-dry Douglas fir 54 beams failed in longitudinal shear at a shearing stress of 313 pounds per square inch (average of the three sets of partially air-dry material).

The results of the tests show that there is no marked difference in strength between fir stringers of red and of yellow color, provided the sticks have the same rate of growth and are equally free from defects.

A series of tests on small, clear, straight-grained sticks indicates that a rate of growth resulting in .21 rings per inch gives the greatest density and strength.

The partially air-dry sticks were tested in from six months to one year from the time of sawing. They were kept in a shed and sprinkled to prevent drying out. The exterior parts of the beams contained less moisture than the centers, but the difference was not marked. An examination of the distribution of the moisture throughout the cross section of the 8 by 16 inch beams showed relations which are exhibited in Diagram IV. A 1-inch cross section taken midway of the stick was divided into 9 parts at third points, as shown, and the moisture in the several parts of the sections determined. The figures in the diagram are the average percentages of moisture found in each part.

<——16 inches——>

<—8 inches—>

22.7 per cent.	24.2 per cent.	22.6 per cent.
25.1 per cent.	27.2 per cent.	24.5 per cent.
22.3 per cent.	24.8 per cent.	22.4 per cent.

Average 23.9 per cent.

DIAGRAM IV.—Distribution of moisture in cross section midway of the length of Douglas fir sticks. (Average of six sections taken from sticks 8 by 16 inches by 16 feet.)

WESTERN HEMLOCK.

The introduction of western hemlock to the market as a building material has met with many obstacles. Without doubt the one offering the greatest opposition to the introduction has been the strong prejudice aroused by the name of hemlock, based upon the qualities of the eastern species. So great is this prejudice even now that, although large quantities of the timber are cut and sold, it is sold under false or fictitious names, such as Alaska pine and Washington pine, spruce, or fir. Western hemlock, as such, has so far had little market standing.

Western hemlock reaches its best development in Washington, in the region lying between the summit of the Cascade Mountains and the coast, but is also found from Alaska to central California and as far east as Idaho and Montana. The tree, where conditions best favor its development, reaches 4 feet in diameter at the butt and 200 feet in height. The trunk is straight and cylindrical, but does not readily clear itself of branches. This causes small knots in the timber and makes it impossible to obtain much clear lumber except from large trees.

The wood of the mature tree is hard, straight and even grained, and nearly white in color. The sour odor of the lumber is unmistakable. There is not the marked difference in either color or hardness between the spring and summer wood that is noticeable in Douglas fir. The wood does not split readily, and is light and tough. These qualities make it especially suitable for box manufacture. Knots are rather frequent, often dark brown to almost black in color, but usually tight and sound. The regular and even structure of the wood and the total absence of pitch render it capable of rapid kiln drying at high temperature without injury.

For flooring, molding, paneling, and all inside finish western hemlock makes a superior lumber, not easily scratched, susceptible of a high polish, and of excellent wearing qualities.

In point of strength, as shown by the tests, western hemlock is suitable for all except the heaviest structures.

The tests of partially air-dried western hemlock recorded in the tables were made upon timbers cut in Washington.

It is difficult to apply to western hemlock the grading rules adopted for Douglas fir, as these rules would throw most of the hemlock sticks into the "seconds" grade. New rules should be made for western hemlock, in order to bring the sticks of better quality into the "merchantable" grade.

Table 7, reference number 12, shows as the average of the results of bending tests on all grades of partially air-dried beams a modulus of rupture of 5,992 pounds per square inch, a modulus of elasticity of 1,351,000 pounds per square inch, and an oven-dry weight per cubic foot of 26 pounds. The rate of growth of these sticks was 12.7 rings per inch.

For all grades of green beams (Table 7, reference number 16) the modulus of rupture is 5,783 pounds per square inch, the modulus of elasticity 1,475,000 pounds per square inch, and the oven-dry weight 28.5 pounds per cubic foot. The moisture in the green beams was 36.2 per cent, against 27.8 per cent for the partially air-dried beams.

Table 11, reference number 5, gives the ratio of the bending strength of the large green sticks to the small sticks cut from them. This ratio is 0.70 for fiber stress at elastic limit, 0.70 for modulus of rupture, and 0.97 for modulus of elasticity.

Table 12, reference number 8, gives the crushing strength of partially air-dry western hemlock as 3,705 pounds per square inch.

Table 13, reference number 4, gives the compressive strength at elastic limit at right angles to grain as 477 pounds per square inch.

Table 14, reference number 4, gives the shearing strength, parallel to grain for small sticks as 746 pounds per square inch.

Table 8, reference number 6, shows that out of 64 tests on western hemlock, 12 failed in longitudinal shear. The shearing stress in the beams failing in longitudinal shear was 273 pounds per square inch.

Approved: JAMES WILSON,
Secretary of Agriculture.

Washington, D. C., September 25, 1907.

APPENDIX.

The revised rules of inspection and grading referred to in this circular are here reproduced.

From the Interstate Rules of 1905 for the Classification and Inspection of Yellow Pine Lumber.

GENERAL RULES.

All lumber must be sound, commercial longleaf yellow pine (pine containing large, coarse knots with coarse grain is excluded under these rules), well manufactured, full to size and saw butted, and shall be free from the following defects: Unsound, loose, and hollow knots, wormholes and knot holes, through shakes or round shakes that show on the surface, and shall be square edge unless otherwise specified.

A through shake is hereby defined to be through or connected from side to side, edge to edge, or side to edge.

Where terms one-half or two-thirds heart are used they shall be construed as referring to the area of the face on which measured.

CLASSIFICATION.

Dimensions.—Dimension sizes shall embrace all sizes 6 inches and up in thickness by 6 inches and up in width. For example: 6 by 6, 6 by 7, 7 by 7, 7 by 8, 8 by 9, and up.

INSPECTION.

*Standard.**—All lumber shall be sound; sap no objection. Wane may be allowed one-eighth of the width of the piece measured across face of wane, extending one-fourth of the length on one corner or its equivalent on two or more corners, provided that not over 10 per cent. of the pieces of any one size shall show such wane.

Merchantable.—All sizes under 9 inches shall show some heart entire length on one side; sizes 9 inches and over shall show some heart the entire length on two opposite sides. Wane may be allowed one-eighth of the width of the piece, measured across face of wane, and extending one-fourth of the length of the piece on one corner or its equivalent on two or more corners, provided that not over 10 per cent. of the pieces of any one size shall show such wane.

Prime Dimension sizes. All square lumber shall show two-thirds heart on two sides and not less than one-half heart on two other sides. Other sizes shall show two-thirds heart on face and show heart two-thirds of length on edges, excepting when the width exceeds the thickness by 3 inches or over; then it shall show heart on the edge for one-half of the length.

From the Pacific coast standard grading rules for Douglas fir [red fir], adopted 1900.

MERCHANTABLE.

This grade shall consist of sound, strong lumber, free from shakes, large, loose, or rotten knots and defects that materially impair its strength; well manufactured and suitable for good substantial constructional purposes.

*Called "square edge" in South Carolina and in this circular.

Will allow—

Occasional variations in sawing or occasional scant thicknesses, sound knots, pitch seams, and sap on corners, one-third the width and one-half the thickness. Defects in all cases to be considered in connection with the size of the piece and its general quality.

SECONDS.

This grade shall consist of lumber having defects which exclude it from grading as merchantable.

Will allow—

Knots and defects which render it unfit for good substantial constructional purposes, but situable for an inferior class of work.

SELECTS.

Shall be sound, strong lumber, good grain, well sawed.

Will allow—

In sizes 6 by 6 and less, knots not to exceed 1 inch in diameter; sap on corners one-fourth the width and one-half the thickness; small pitch seams when not exceeding 6 inches in length.

In sizes over 6 by 6, knots not to exceed 2 inches in diameter, varying according to the size of the piece; sap on corner not to exceed 3 inches on both face and edge; pitch seams not to exceed 8 inches in length.

Defects in all cases to be considered in connection with the size of the piece and its general quality.

DESCRIPTION OF MATERIAL.

The limits of this circular will not allow a detailed description of the sticks tested, but in order to show the nature of the information collected the following descriptions are given:

HISTORY OF SHIPMENT "A" DOUGLAS FIR.

Cut in township 17 south, range 2 east, Willamette meridian, on McKenzie River, west slope Cascade Mountains, Lane County, Oregon. Shipped from Coburg, Ore., May 8; received at Barkeley, Cal., May 25, 1903.

Douglas fir, shipment "A," 6 by 8 average select.

Rings per inch, 13; color, medium yellow; imperfections: Side *a*, one weather check; side *b*, pitch seam; side *c*, pitch seam, weather checks; side *d*, pitch seam; weather checks.

Douglas fir, shipment "A," 6 by 8 maximum select.

Rings per inch, 20.5; color, medium yellow; imperfections: Side *a*, three knots 0.5 to 0.7 inch in diameter, small weather checks; side *b*, clear; side *c*, weather checks; side *d*, clear.

Douglas fir, shipment "A," 6 by 8 minimum select.

Rings per inch, 21; color, medium yellow; imperfections: Side *a*. weather checks; side *b*, pitch seam; side *c*, one-half inch knot and weather checks; side *d*, pitch seam.

Douglas fir, shipment "A," 6 by 8 average merchantable.

Rings per inch, 22; color, medium red; imperfections: Side *a*, 2 knots about 1 inch in diameter, weather checks; side *b*, 1 knot 3 by 2½ inches, broken out; side *c*, 6 knots 1 to 1½ inches in diameter, checks; side *d*, 1 small knot.

Douglas fir, shipment "A," 6 by 8 maximum merchantable.

Rings per inch, 22 color, medium yellow; imperfections: Side *a*, clear; side *b*, clear; side c, two ½-inch sound knots; side *d*, clear.

Douglas fir, shipment "A," 6 by 8 minimum merchantable.

Rings per inch, 25; color, medium yellow; imperfections: Side *a*, one ½-inch sound knot; side *b*, clear; side *c*, 8 knots from ½ to 1 inch in diameter; side *d*, 2 knots.

Douglas fir, shipment "A," 6 by 8 average seconds.

Rings per inch, 8; color, medium red; imperfections: Side *a*, 16 sound knots ½ to 2 inches in diameter, check; side *b*, 4 knots 1 to 1½ inches in diameter, sound; side *c*, 6 loose knots 1 to 1½ inches in diameter, checked; side *d*, 5 knots from 1 to 1½ inches in diameter, all sound.

Douglas fir, shipment "A," 6 by 8 maximum seconds.

Rings per inch, 18; color, medium red; imperfections: Side *a*, 3 knots 1 to 2½ inches in diameter, 2 loose; side *b*, 7 knots 1 to 3 inches in diameter, loose; side *c*, 4 loose knots 1 inch in diameter, pitch seam; side *d*, no knots, pitch seam and check.

Douglas fir, shipment "A," 6 by 8 minimum seconds.

Rings per inch, 5.4; color, medium red; imperfections: Side *a*, 13 knots ½ to 1½ inches in diameter, 2 loose, weather checks; side *b*, 5 knots ½ to 1½ inches in diameter, 2 loose; weather checks; side *c*, 5 knots ½ to 1½ inches in diameter, 1 loose, weather checks; side *d* 11 knots ½ to 2 inches in diameter, 3 loose, weather checks.

Loblolly pine, 8 by 8 average square edge, green.

History: From Urban Wharf, King and Queen County, Va.; in yard one week. Rings per inch, 2.6; color, light yellow; imperfections: Side *a*, 11 knots from 1 to 3 inches in diameter, all sap; side *b*, 6 knots about 2 inches in diameter, all sap; side *c*, 6 knots from 2½ to 4½ inches in diameter, all sap; side *d*, 9 knots from 1½ to 3 inches in diameter, all sap.

Loblolly pine, 8 by 8 maximum square edge, green.

Rings per inch, 3.2; color, light yellow; imperfections: Side *a*, 8 knots from 1 to 2½ inches in diameter; side *b*, 7 knots from 1½ to 3 inches in diameter; side *c*, 5 knots from ½ to 3 inches in diameter; side *d*, 7 knots from 1 to 4 inches in diameter, sap on all four faces.

Loblolly pine, 8 by 8 minimum square edge, green.

Rings per inch, 3; color, light yellow, turning to yellowish white on exposure; imperfection: Side *a*, 3 knots; side *b*, 6 knots; side *c*, 7 knots; side *d*, 8 knots from 3 to 5 inches in diameter.

Western hemlock, 8 by 16 maximum merchantable.

History: Cut in township 20 south, range 1 east, Williamette meridian, west slope Cascade Mountains, Lane County, Oregon. Shipped from Saginaw May 12, received at Berkeley, Cal., May 25, 1903. Rings per inch, 11.8; imperfections: Side *a*, 11 knots ½ to 1 inch in diameter, 3 loose, weather checks; side *b*, badly weather checked; side *c*, 10 knots ½ to 1 inch in diameter, 6 loose, weather checked; side *d*, 2 knots 1½ inches in diameter, sound, weather checked.

Western hemlock, 8 by 16 minimum merchantable.

Rings per inch, 11; imperfections: Side *a*, 10 small knots ½ to 1½ inches in diameter, 4 loose, 6 sound; side *b*, 3 knots, 2 loose; side *c*, 8 knots, all sound, checked; side *d*, 2 knots, both loose, weather checked.

Loblolly pine, 8 by 14 average square edge.

History: Felled about September 1, 1903; sawed at mill September 15; tested November 4, 1903. Rings per inch, 7; color, sap, greenish white; imperfections: Side *a*, all sap; side *b*, three-fourths sap; side *c*, all sap; side *d*, 7 knots 1 to 1½ inches in diameter, two-thirds sap.

Loblolly pine, 8 by 14 maximum square edge.

Rings per inch, 6; color, heart, brown; sap, greenish white; imperfections: Side *a*, all sap; side *b*, 10 knots ½ to 3½ inches in diameter, one-half sap; side *c*, all sap; side *d*, one ½-inch knot; two-thirds sap.

Loblolly pine, 8 by 14 minimum square edge.

Rings per inch, 5.8; color, sap, greenish white, heart, brown; imperfections; side *a*, all sap; side *b*, seven-eighths sap, one 2-inch knot; side *c*, all sap; side *d*, nine-tenths sap.

Longleaf pine, 10 by 12 average merchantable.

History: Grown in southern Georgia; in lumber yard since February, 1902; tested September 24, 1902. Rings per inch, 13; imperfections: Side *a*, 1½ by 2½ inch knot in upper half of side; side *b*, 2 small knots in upper half of side, 1.1 by ½ inch and 1½ by 1¼ inch; side *c*, 4 small knots in center of side, 0.2 by 0.25 inch, 1.4 by 0.2 inch, 1.2 by 2 inch, and 0.7 by 0.5 inch; side *d*, 4 small knots and slight checks near upper end, 1.0 by 0.25 inch, 2.2 by 0.2 inch, 1.1 by 0.25 inch, 1.0 by 0.6 inch.

Longleaf pine, 10 by 12 maximum merchantable.

Rings per inch, 14; imperfections: A few slight checks in each side; 1 knot in side *a*, 3 by 4 inches, and 1 in side *d*, 2.5 by ½ inches.

Longleaf pine, 10 by 12 minimum merchantable.

Rings per inch, 13; imperfections: Side *a*, 3 knots, ½ by ½ inch, ½ by ½ inch, ¼ by ¼ inch, checks; side *b*, 4 knots, 1½ by 1½ inches, 1½ by 1½ inches, 1 by 1 inch, 1 by 1 inch; side *c*, 6 knots, ½ by ½ inch, ½ by ½ inch, 1 by 1½ inches, 1 by 1 inch, ½ by ½ inch, 1 by 1 inch; side *d*, 1 knot ½ by ½ inch.

TABLE 2.—*Bending strength of large sticks.*

LOBLOLLY PINE.

Reference number.	Locality of growth.	Dimensions. Section.	Dimensions. Span.	Grade.	Condition of seasoning.		Number of tests.	Moisture per cent.	Rings per inch.	Specific gravity, dry.	Weight per cu. ft. As tested.	Weight per cu. ft. Oven dry.	Fiber stress at elastic limit.	Modulus of rupture	Modulus of elasticity.	Elastic resilience.	Number failing by longit. shear.	Remarks.
											Lbs.	*Lbs.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Inch lbs. per cu. in.*		
1	South Carolina..	6"x 7" 6"x10" 4"x12" 6"x16" 8"x14" 8"x16"	10'0" to 15'6".	Square edge..	Green........	Average....	42	48.0	5.7	0.50	46.2	31.2	3,150	5,580	1,426	0.45	7	Moisture above saturation point in all cases.
						Maximum..		92.1	11.7	.60	56.8	37.5	5,210	8,460	1,920	.99		
						Minimum...		30.2	2.3	.40	35.6	25.0	1,675	3,120	905	.07		
2	South Carolina..	6"x 7" 4"x12" 6"x10" 6"x16" 8"x16" 10"x16"	10'0" to 16'0".	Square edge..	Partially air dry.	Average....	18	27.7	5.0	.50	40.0	31.2	3,380	5,650	1,435	.45	0	Moisture from 25 to 30 per cent.
						Maximum..		29.2	8.2	.55	43.7	34.4	4,610	8,090	1,880	.76		
						Minimum...		25.5	2.5	.45	35.6	28.1	2,115	3,600	1,152	.20		
3	South Carolina..	6"x 7" 4"x12" 6"x10" 6"x16"	10'0" to 15'0".	Square edge.	Partially air dry.	Average....	19	21.0	5.6	.50	37.5	31.2	2,970	5,000	1,340	.60	2	Moisture less than 25 per cent.
						Maximum..		24.9	17.2	.58	45.6	36.2	4,850	8,100	2,040	.69		
						Minimum...		15.0	2.7	.41	31.2	25.6	1,730	2,910	906	.10		
4	Virginia........	8"x 8"	6'0" to 16'0".	Square edge..	Partially air dry.	Average....	12	22.4	4.8	.46	35.6	28.8	3,260	5,180	1,180	.51	0	
						Maximum..		27.7	8.8	.58	43.1	36.2	5,300	8,950	1,728	1.05		
						Minimum...		17.8	2.5	.37	30.0	23.1	1,280	2,180	606	.13		
5	Virginia........	8"x 8"	6'0" to 15'6".	Square edge..	Green........	Average....	17	64.0	3.0	.43	43.7	26.9	1,935	3,490	744	.31	0	Very rapid growth; poor quality.
						Maximum..		100.5	4.0	.51	51.9	31.9	3,185	4,720	1,193	.78		
						Minimum...		33.8	2.5	.35	35.0	21.9	956	2,180	357	.12		

LONGLEAF PINE.

6	South Carolina..	6"x 8" 10"x16"	15'0"..	Merchantable..	Partially air dry.	Average....	22	25.0	13.7	0.58	45.6	36.2	3,800	7,160	1,560	0.53	9	
						Maximum..		40.3	25.4	.76	60.0	47.5	4,970	10,020	2,010	.78		
						Minimum...		17.3	6.2	.50	39.4	31.2	2,220	5,450	1,190	.21		
7	Georgia........	10"x12"	15'0"..	Merchantable..	Partially air dry.	Average....	22	27.3	18.0	.69	54.7	42.9	5,581	8,384	1,820	......	6	Excellent merchantable grade.
						Maximum..		34.5	29.0	.79	......	49.4	9,600	11,410	2,920	......		
						Minimum...		20.0	11.0	.50	......	31.4	3,547	4,836	1,167	......		

TAMARACK.

8	Minnesota......	4"x10" 6"x12"	13'6"..	Merchantable..	Green........	Average....	30	50.6	14.0	0.48	45.2	30.1	2,810	4,562	1,219	0.62	4	
						Maximum..		72.1	24.4	.60	52.9	37.6	3,750	6,080	1,538	1.02		
						Minimum...		31.4	7.3	.43	39.6	26.9	1,431	2,040	797	.24		

NORWAY PINE.

9	Minnesota......	4"x10" 4"x12" 6"x12"	13'6"..	Merchantable..	Green........	Average....	49	47.8	13.6	0.41	37.4	25.4	2,550	3,975	1,189	0.52	7	
						Maximum..		85.8	32.4	.48	45.6	29.9	3,915	5,625	1,700	1.03		
						Minimum...		29.5	6.7	.35	29.7	20.9	1,600	2,810	808	.22		

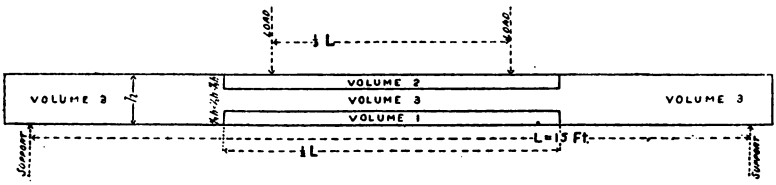
TABLE 3.—*Loblolly pine—Bending tests on beams seasoned under different conditions.*

[8″x16″ section—13½′ to 15′ span.]

	Number of tests.	Fiber stress at elastic limit.	Modulus of rupture.	Longitudinal shear at max. load.	Modulus of elasticity.	Moisture per cent.	Rings per inch.	Weight per cu. ft. oven dry.	Condition of seasoning.
		Lbs. per sq. in.	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*			*Lbs.*	
Average...	4	3,580	5,480	364_4	1,780	23.2	9.4	33.7	Air dry 3½ months in the open.
Maximum..		4,070	6,600	440	1,987	24.3	11.5	34.5	
Minimum..		3,090	5,000	327	1,530	21.5	8.0	32.5	
Average...	5	4,512	5,060	333_3	1,685	20	7.7	33.9	Kiln dry 6 days.
Maximum..		5,840	7,320	488	1,790	22	10.2	38.0	
Minimum..		3,180	2,150	143	1,410	18	4.7	27.7	
Average...	12	4,331	6,721	493_9	1,688	......	7.7	....	Air dry 21 months under shelter.
Maximum.		4,990	8,560	620	2,002	......	9.5	....	
Minimum..		3,110	5,160	380	1,398	......	5.5	....	

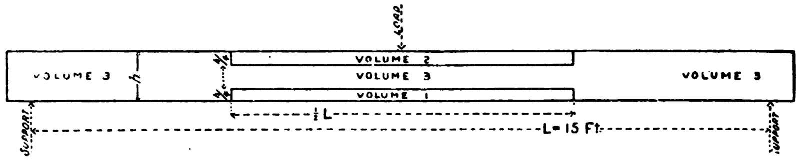
NOTE.—Figures written as subscripts to the figures for longitudinal shear indicate the number of sticks failing n that manner.

TABLE 4.—*Loblolly pine—Effect of knots; beams loaded at two points.*



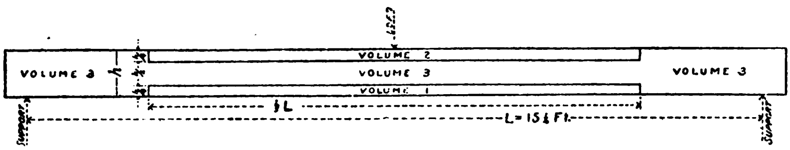
		Number of tests.	Per cent. of sap.	Rings per inch.	Moisture, per cent.	Specific gravity dry.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Longitudinal shear at maximum load.	Number failing due to defect in volume.
							Lbs. per sq. in.	Lbs. per sq. in.	1,000 lbs. per sq. in.	Lbs. per sq. in.	
Group 1. Sticks having defects in volume 1.	Average..	33	42	5.6	65	0.495	2,830	4,580	1,365	228	23
	Maximum		92	8.2	101	.578	3,820	6,130	1,875	307	
	Minimum.		8	3.2	40	.438	2,050	2,300	912	114	
Group 2. Sticks having defects in volume 2 and not in volume 1.	Average..	15	52	6.2	75	.481	3,000	5,030	1,375	252	12
	Maximum		85	10.0	101	.510	3,810	6,510	1,623	325	
	Minimum.		0	4.0	38	.440	2,010	3,640	1,070	182	
Group 3. Sticks having defects in volume 3 and not in volumes 1 and 2.	Average..	11	45	6.5	57	.460	3,820	6,390	1,675	318	0
	Maximum		93	9.2	62	.470	4,540	7,260	2,040	363	
	Minimum.		12	5.5	47	.440	3,310	5,420	1,260	271	
Relative values.											
Group 3.......	....	......	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	......
Group 2.......	....	......	93.3	95.5	131.7	104.4	78.6	78.6	82.1	79.2	......
Group 1.......	....	......	115.5	86.2	114.0	107.7	74.1	71.7	81.5	71.7	......
Minors free from defects.											
Cut from group 1.	Average..	19	....	6.0	23.6	.452	4,766	7,798	1,360	259	......
	Maximum		....	10.0	34.7	.536	6,080	9,030	1,652	298	......
	Minimum.		....	3.0	19.6	.397	2,860	5,790	797	192	......
Cut from group 2.	Average..	12	....	8.2	28.0	.482	4,730	8,230	1,585	273	......
	Maximum		....	12.0	51.1	.527	5,770	9,110	2,154	301	......
	Minimum.		....	5.5	21.6	.448	3,770	6,930	1,076	229	......
Cut from group 3.	Average..	20	....	9.6	23.6	.510	5,170	9,260	1,550	306	......
	Maximum		....	28.0	26.5	.692	6,500	12,470	1,880	412	......
	Minimum.		....	3.0	20.4	.438	4,220	7,070	1,075	235	......
Relative values.											
Group 3.......	....	......	......	100.0	100.0	100.0	100.0	100.0	100.0	100.0	......
Group 2.......	....	......	......	85.5	118.6	94.6	91.5	88.8	102.5	89.3	......
Group 1.......	....	......	......	62.5	100.0	88.7	92.3	84.2	87.7	84.6	......

TABLE 5.—*Loblolly pine—Effect of knots; beams loaded at center.*



		Number of tests.	Per cent. of sap.	Rings per inch.	Moisture, per cent.	Specific gravity dry.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Longitudinal shear at maximum load.	Number failing due to defect in volume.
							Lbs. per sq. in.	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*	
Group 1. Sticks having defects in volume 1.	Average..		33	4.6	54	49	2,660	4,420	1,210	152	
	Maximum	21	100	8.0	120	62	3,320	5,720	1,475	182	17
	Minimum.		3	2.6	28	40	1,600	2,810	887	94	
Group 2. Sticks having defects in volume 2 and not in volume 1.	Average..		21	6.5	36	50	3,607	5,930	1,350	200	
	Maximum	4	30	10.7	47	55	4,370	7,120	1,785	237	2
	Minimum.		15	5.0	30	47	3,270	4,890	1,180	168	
Group 3. Sticks having defects in volume 3 and not in volumes 1 and 2.	Average..		49	6.0	62	50	3,380	5,800	1,500	193	
	Maximum	9	98	9.3	103	54	4,200	6,450	1,930	210	0
	Minimum.		5	4.1	28	46	2,880	4,860	1,063	170	
Relative values.											
Group 3......	....	.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	......
Group 2......	....	.....	43.0	108.0	58.0	100.0	107.0	102.0	90.0	103.5	......
Group 1......	....	.....	67.3	76.7	87.0	98.0	78.7	76.3	80.7	79.0	......

TABLE 6.—*Douglas fir—Effect of knots; beams loaded at center.*



		Number of tests.	Rings per inch.	Moisture, per cent.	Specific gravity dry.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Longitudinal shear at maximum load.
						Lbs. per sq. in.	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sv. in.*
Group 1. Sticks having defects in volume 1.	Average....	75	9.8	30.8	.454	3,720	5,540	1,435	236
	Maximum..		20.0	36.9	.509	5,860	8,270	1,945	350
	Minimum...		3.5	23.7	.390	2,050	2,930	947	125
Group 2. Sticks having defects in volume 2 and not in volume 1.	Average....	30	12.2	31.3	.472	4,298	6,590	1,575	282
	Maximum..		23.4	35.1	.550	5,920	8,210	2,000	345
	Minimum...		5.2	21.8	.410	2,960	4,120	1,305	175
Group 3. Sticks having defects in volume 3 and not in volumes 1 and 2.	Average....	30	12.0	30.9	.483	4,650	7,130	1,710	302
	Maximum...		25.5	37.1	.543	5,900	9,000	2,070	381
	Minimum...		6.6	22.3	.429	3,020	3,720	1,370	218
Relative values:									
Group 3............	....	......	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Group 2.	....	......	101.5	101.3	97.7	92.5	92.4	92.2	93.3
Group 1............	....	......	81.7	99.7	94.0	80.1	77.7	83.9	78.2
Minors free from defects.									
Cut from group 1.....	Average....	97	10.5	30.3	.448	5,230	7,970	1,610	332
	Maximum..		23.1	43.5	.537	8,220	10,700	3,035	444
	Minimum...		3.3	23.0	.389	2,560	5,140	612	215
Cut from group 2.....	Average....	74	12.9	29.9	.473	5,730	8,690	1,880	361
	Maximum..		29.1	44.5	.585	8,020	11,550	2,923	481
	Minimum...		3.5	22.7	.319	3,090	5,850	1,230	244
Cut from group 3.....	Average....	99	12.0	29.5	.482	5,880	8,880	1,810	371
	Maximum..		23.1	40.0	.568	8,220	10,450	3,646	444
	Minimum...		3.3	24.1	.403	2,560	5,140	612	215
Relative values.									
Group 3............	....	......	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Group 2............	....	......	107.5	101.5	98.2	97.6	97.8	104.0	97.3
Group 1............	....	......	87.5	102.8	92.9	90.5	89.8	88.9	89.5

TABLE 7.—*Bending strength of large sticks.*

DOUGLAS FIR.

Reference No.	Locality of growth.	Dimensions. Section.	Dimensions. Span.	Grade.	Condition of seasoning.		Number of tests.	Moisture per cent.	Rings per inch.	Specific gravity dry.	Weight per cu. ft. As tested.	Weight per cu. ft. Oven dry.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Elastic resilience.	Number failing by longit. shear.
											Lbs.	*Lbs.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Inch-lbs. per cu. in.*	
1	Oregon and Washington.	8″x16″	7′ and 16′	Select	Partially air dry	Average	84	21.8	18.8	0.46	35.0	28.8	5,579	8,184	1,725	1.02	31
		6″x 8″				Maximum		30.5	33.0	.57	......	35.6	9,300	11,880	2,665	2.66	
		5″x 8″				Minimum		13.1	7.0	.37	......	22.9	2,730	4,560	1,110	.34	
2	Oregon and Washington.	8″x16″	7′ and 16′	Merchantable	Partially air dry	Average	80	22.4	14.1	.43	32.6	26.7	4,754	6,876	1,597	.81	17
		6″x 8″				Maximum		36.5	33.0	.55	......	34.1	7,630	11,620	2,334	1.89	
		5″x 8″				Minimum		11.7	4.0	.31	......	19.1	2,910	4,150	1,047	.38	
3	Oregon and Washington.	8″x16″	7′ and 16′	Second	Partially air dry	Average	52	22.2	10.6	.44	33.7	27.6	3,858	5,106	1,408	.61	6
		6″x 8″				Maximum		34.7	27.0	.51	......	31.9	6,570	9,970	2,000	1.53	
		5″x 8″				Minimum		13.5	4.0	.37	......	22.8	1,290	1,980	762	.10	
4	Oregon and Washington.	8″x16″	7′ and 16′	All grades	Partially air dry	Average	216	22.1	15.1	.45	33.8	27.7	4,859	6,975	1,600	.85	54
		6″x 8″				Maximum		36.5	33.0	.57	......	35.6	9,300	11,880	2,665	....	
		5″x 8″				Minimum		11.7	4.0	.31	......	19.1	1,290	1,980	762	....	
5	Oregon	8″x16″	16′	Select	Green	Average	52	31.2	11.7	.48	39.4	30.0	4,370	6,720	1,660	....	14
						Maximum		37.1	25.5	.54	......	......	5,900	9,000	2,070	....	
						Minimum		22.3	6.0	.41	......	......	2,960	3,720	1,265	....	
6	Oregon	8″x16″	16′	Merchantable	Green	Average	51	31.4	10.7	.46	37.7	28.7	4,030	6,140	1,510	....	10
						Maximum		36.9	23.0	.55	......	......	5,920	8,750	1,895	....	
						Minimum		21.8	4.8	.39	......	......	2,640	3,900	1,050	....	
7	Oregon	8″x16″	16′	Second	Green	Average	32	29.8	9.6	.46	37.2	28.7	3,590	5,200	1,340	....	
						Maximum		36.8	20.0	.50	......	......	5,860	8,270	1,945	....	
						Minimum		23.7	3.5	.41	......	......	2,010	2,930	947	....	
8	Oregon	8″x16″	16′	All grades	Green	Average	135	30.9	10.8	.47	38.4	29.4	4,050	6,140	1,526	....	26
						Maximum		37.1	25.5	.55	......	......	5,920	9,000	2,070	....	
						Minimum		21.8	3.5	.39	......	......	2,010	2,930	947	....	

WESTERN HEMLOCK.

9	Oregon and Washington.	8"x16" 6"x 8"	7' and 16'	Select........	Partially air dry.	Average....	19	25.8	15.5	0.42	32.7	26.0	4,370	6,876	1,373	....	3
						Maximum..		36.8	30.0	....	......	31.7	6,380	9,100	2,081	....	
						Minimum...		18.0	9.0	....	......	21.1	2,963	3,980	965	....	
10	Oregon and Washington.	8"x16" 6"x 8"	7' and 16'	Merchantable..	Partially air dry.	Average....	23	27.0	13.1	.42	33.5	26.4	3,870	6,143	1,446	....	7
						Maximum..		45.8	19.0	....	......	28.4	5,124	7,970	1,670	....	
						Minimum...		15.3	8.0	....	......	22.4	2,660	3,420	1,100	....	
11	Oregon and Washington.	8"x16" 6"x 8"	7' and 16'	Second.......	Partially air dry.	Average....	22	30.0	9.6	.41	33.5	25.8	3,398	5,071	1,231	....	2
						Maximum..		51.2	14.5	....	......	28.0	4,690	6,470	1,464	....	
						Minimum...		18.2	6.0	....	......	23.2	2,270	3,900	985	....	
12	Oregon and Washington.	8"x16" 6"x 8"	7' and 16'	All grades....	Partially air dry.	Average....	64	27.8	12.7	.42	33.2	26.0	3,856	5,992	1,351	....	12
						Maximum..		51.2	30.0	....	......	31.7	6,380	9,100	2,081	....	
						Minimum...		15.3	6.0	....	......	21.1	2,270	3,420	965	....	
13	Washington.....	8"x16"	16'	Select........	Green..........	Average....	9	34.0	20.4	.47	39.8	29.6	3,870	5,960	1,494	0.57	4
						Maximum..		58.5	27.2	.53	51.7	32.9	4,570	7,075	1,800	.80	
						Minimum...		25.8	12.4	.43	34.1	26.6	2,875	4,270	1,095	.32	
14	Washington.....	8"x16"	16'	Merchantable..	Green..........	Average....	9	41.5	19.8	.47	41.2	29.1	3,725	5,800	1,536	.50	5
						Maximum..		64.2	28.1	.55	51.6	34.2	4,580	7,050	1,788	.65	
						Minimum...		21.5	10.3	.40	33.8	25.3	3,160	4,710	1,480	.37	
15	Washington.....	8"x16"	16'	Second.......	Green..........	Average....	12	33.9	18.8	.44	36.2	27.3	3,650	5,637	1,414	.52	7
						Maximum..		55.2	26.5	.48	43.1	29.8	3,975	6,360	1,721	.60	
						Minimum...		23.5	9.2	.40	32.4	24.6	3,200	4,930	1,236	.42	
16	Washington.....	8"x16"	16'	All grades....	Green..........	Average....	30	36.2	19.6	.46	38.8	28.5	3,738	5,783	1,475	.53	16
						Maximum..		64.2	28.1	.55	51.7	34.2	4,580	7,075	1,800	.80	
						Minimum...		21.5	9.2	.40	32.4	24.6	2,875	4,270	1,095	.32	

TABLE 8.—*Longitudinal shear in bending.*

Reference No.	Locality of growth.	Dimensions.	Condition of seasoning.	Moisture per cent.	Weight per cu. ft., oven dry.	Rings per inch.	Sticks failing in shear. Number of tests.	Sticks failing in shear. Longitudinal shear at maximum load in lbs. per sq. in. Average.	Maximum.	Minimum.	Sticks not failing in shear. Number of tests.	Sticks not failing in shear. Longitudinal shear at maximum load in lbs. per sq. in. Average.	Maximum.	Minimum.
						LOBLOLLY PINE.								
					Lbs.									
1	South Carolina	6"x 7"x10" to 8"x16"x16'.	Green	48.0	31.2	5.7	7	339	431	256	35	258	442	100
2	South Carolina	8"x16"x16'	Partially air dry	....	....	7.7	9	510	620	432	3	440	471	380
						LONGLEAF PINE.								
3	South Carolina	6"x8"x16' to 10"x16"x16'.	Partially air dry	25.0	36.2	13.7	9	335	388	261	13	191	320	115
						DOUGLAS FIR.								
4	Oregon and Washington	6"x 8"x 7'	Partially air dry	23.5	27.5	16.9	6	475	601	272	26	400	563	219
		6"x 8"x16'		22.4	27.9	15.8	7	300	517	146	96	146	413	54
		8"x16"x16'		21.3	27.6	13.5	41	291	395	173	40	244	390	100
5	Oregon	8"x16"x16'	Green	30.9	29.4	10.8	26	268	....	....	109	260	....	....
						WESTERN HEMLOCK.								
6	Oregon and Washington	6"x 8"x 7'	Partially air dry	28.9	26.4	11.5	5	304	343	270	27	296	480	188
		8"x16"x16'		26.8	25.6	13.8	7	250	325	131	25	222	318	136
						TAMARACK.								
7	Minnesota	6"x12"x16'	Green	57.6	29.1	16.6	4	261	313	228	11	253	329	115
8	Minnesota	6"x12"x16'	Partially air dry	23.0	30.8	15.1	3	300	315	290	2	345	424	266
						NORWAY PINE.								
9	Minnesota	4"x10"x16'	Green	45.6	25.8	13.3	1	234	234	234	15	195	266	149
		4"x12"x16'		47.8	25.9	12.5	4	268	313	227	14	230	318	160
		6"x12"x16'		50.3	24.9	14.7	2	216	249	184	13	199	255	158
10	Minnesota	4"x10"x16'	Partially air dry	13.7	28.0	12.0	1	278	278	278	4	327	362	236
11		6"x12"x16'		16.7	26.3	8.1	0	....	....	....	5	286	293	271

NOTE.—In the tests listed under longleaf pine only the materinl from South Carolina was used..

TABLE 9.—*Distribution of moisture lengthwise in 20 sticks of North Carolina loblolly pine.*

Stick No.	Moisture per cent.		Stick No.	Moisture per cent.		Stick No.	Moisture per cent.	
	Section from center.	Section from quarter point.		Section from center.	Section from quarter point.		Section from center.	Section from quarter point.
53	36.1	35.1	60	29.7	30.7	67	47.6	54.4
54	26.5	25.7	61	40.0	36.3	68	55.1	41.6
55	35.2	35.3	62	36.4	38.3	69	36.5	33.9
56	27.9	27.9	63	30.0	28.3	70	36.3	27.1
57	27.4	27.1	64	41.5	43.3	71	46.4	45.8
58	28.8	28.6	65	30.9	31.2	72	58.2	60.3
59	27.9	27.7	66	50.8	49.9			

Moisture determined at center and at one-quarter point. Sticks 8 by 14 inches by 16 feet.

TABLE 10.—*Distribution of moisture lengthwise in 18 sticks of longleaf and loblolly pine.*

Stick No.	Moisture per cent.		Stick No.	Moisture per cent.		Stick No.	Moisture per cent.	
	Section from center.	Section from quarter point.		Section from center.	Section from quarter point.		Section from center.	Section from quarter point.
81	19.4	18.6	87	19.8	19.5	100	30.6	31.6
82	24.4	22.2	88	24.4	24.3	126	82.5	86.5
83	19.2	19.7	89	18.5	17.6	127	43.4	37.4
84	20.8	19.8	95	26.4	24.8	128	84.9	59.7
85	19.2	19.4	98	51.6	50.4	144	28.7	28.5
86	18.4	21.6	99	45.9	40.6	152	24.6	24.9

Moisture determined at center and side quarter points. Sticks 6 by 7 to 10 by 16 inches by 16 feet.

TABLE 11.—*Comparative bending strength of large and small sticks.*

Reference No.	Locality of growth.	Dimensions.		Number of tests.	Rings per inch.	Moisture per cent.	Average.			Maximum.			Minimum.		
		Section.	Span.				Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.
	LOBLOLLY PINE (GREEN).														
							Lbs. per sq. in.	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in;*	*1,000 lbs. per sq. in.*
1	South Carolina........	6"x7" to 8"x16".	10'0" to 15'6"..	42	5.7	48.0	3,150	5,580	1,426	5,210	8,460	1,920	1,675	3,120	905
		2"x2".........	30"...........	44	5.4	70.9	4,100	7,870	1,440	6,190	10,670	2,260	2,250	4,110	712
	Ratio of large sticks to small.	....	....	......	......	......	.77	.71	.99	.84	.79	.85	.75	.76	1.27
	LONGLEAF PINE (PARTIALLY AIR DRY).														
2	South Carolina........	6"x8" and 10"x16"	180"...........	22	13.7	25.0	3,800	7,160	1,560	4,970	10,020	2,010	2,220	5,450	1,190
		2"x2".........	30"...........	15	14.1	33.9	4,950	9,070	1,540	6,190	10,820	2,110	2,250	7,910	1,107
	Ratio of large sticks to small.	....	....	......	......	......	.77	.79	1.01	.80	.93	.95	.99	.69	1.08
	DOUGLAS FIR (PARTIALLY AIR DRY AND GREEN).														
3	Washington...........	8"x16".........	192"...........	57	16.3	20.6	4,710	6,940	1,638	6,360	8,750	2,203	2,930	4,560	1,175
		2"x 2".........	24"...........	119	17.9	20.6	6,110	9,840	1,656	8,640	12,410	2,270	3,340	5,310	1,256
	Ratio of large sticks to small.	....	....	......	......	......	.77	.71	.99	.74	.70	.97	.88	.86	.94
4	Oregon...............	8"x16".........	192"...........	135	10.8	30.9	4,050	6,140	1,526	5,920	9,000	2,070	2,010	2,930	947
		2"x 2".........	24"...........	259	11.8	30.2	5,680	8,500	1,760	8,220	11,550	3,810	2,560	5,140	612
	Ratio of large sticks to small.	....	....	......	......	......	.71	.72	.87	.72	.78	.54	.79	.57	1.55

WESTERN HEMLOCK (GREEN).

5	Washington	6"x8" and 8"x16"	84" and 192"	32	10.2	32.2	3,660	5,560	1,320	5,124	7,190	1,665	2,270	3,900	1,005
		2"x2"	24"	42	11.6	27.3	5,198	7,905	1,357	6,280	10,500	1,728	3,510	5,100	955
	Ratio of large sticks to small.						.70	.70	.97	.82	.69	.96	.65	.77	1.05

TAMARACK (GREEN).

6	Minnesota	4"x10" to 6"x12"	162"	30	14.0	50.6	2,810	4,562	1,219	3,750	6,080	1,538	1,431	2,040	797
		2"x2"	30"	82	14.0	38.8	3,274	5,776	959	5,680	8,740	1,570	2,280	4,580	640
	Ratio of large sticks to small.						.86	.79	1.27	.66	.70	.98	.63	.45	1.25

NORWAY PINE (GREEN).

7	Minnesota	4"x10" to 6"x12"	162"	49	13.6	47.8	2,550	3,975	1,189	3,915	5,625	1,700	1,600	2,810	808
		2"x2"	30"	133	11.4	32.3	2,808	5,173	960	5,100	7,610	1,578	1,420	3,070	495
	Ratio of large sticks to small.						.91	.77	1.24	.77	.74	1.08	1.13	.92	1.63

TABLE 12.—*Compressive strength parallel to grain.*

Reference No.	Locality of growth.	Dimensions. Section.	Dimensions. Length.	Condition of seasoning.		Number of tests. of tests.	Moisture per cent.	Rings per inch.	Weight per cu. ft. As tested.	Weight per cu. ft. Oven dry.	Compressive strength at elastic limit.	Crushing strength at maximum load.
									Lbs.	*Lbs.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
	LOBLOLLY PINE.											
1	South Carolina	4"x8" to 5"x7"	12" to 30"	Partially air dry	Average	38	24.5	7.1	40	32	2,710	4,250
					Maximum		29.1	18.4			3,900	5,330
					Minimum		19.7	3.0			1,200	2,660
2	South Carolina	4"x8" to 5"x7"	12" to 30"	Green	Average	25	54.9	5.0	44	28	2,390	3,510
					Maximum		117.0	8.0			2,890	4,325
					Minimum		31.3	3.0			1,602	2,560
3	Virginia	4"x6" to 8"x8"	16" to 30"	Partially air dry	Average	10	22.6	4.9	36	29	2,217	2,950
					Maximum		27.7	8.8			3,210	4,490
					Minimum		17.8	2.5			1,170	1,580
4	Virginia	8"x8"	18" to 32"	Green	Average	14	63.4	3.4	44	27	1,510	2,140
					Maximum		100.5	4.0			2,410	2,590
					Minimum		33.8	2.5			977	1,603
	LONGLEAF PINE.											
5	Georgia	4"x5" to 5"x6"	16"	Partially air dry	Average	46	26.3	18.0	46	36	3,480	4,800
					Maximum		34.8	29.0			5,010	5,950
					Minimum		21.7	11.0			2,397	3,290
	DOUGLAS FIR.											
6	Washington and Oregon	6"x6"	18" to 30"	Partially air dry	Average	422	20.5	14.5	34	27.8	3,139	4,406
					Maximum		35.3	36.0			5,620	7,700
					Minimum		12.1	2.0			985	1,620
7	Oregon	6"x6"	18"	Green	Average	428	30.9	10.0	37.8	28.9	2,840	3,500
					Maximum		44.5	25.3			5,000	5,380
					Minimum		23.3	3.0			1,390	1,910

WESTERN HEMLOCK.

8	Washington and Oregon	6"x6"	12" to 30"	Partially air dry	Average	130	25.4	12.1	32	25.3	2,840	3,705
					Maximum		44.6	29.0	......	......	5,230	5,850
					Minimum		16.0	5.5	......	......	1,340	2,455

TAMARACK.

9	Minnesota	4"x7" to 6"x7"	30"	Partially air dry	Average	10	36.6	12.0	46	31	2,394	3,229
					Maximum		74.7	15.8	......	......	2,930	3,650
					Minimum		23.1	8.5	......	......	1,670	2,380
10	Minnesota	3½"x3½"	30"	Air dry	Average	62	17.0	13.0	38.0	32.5	3,050	4,230
					Maximum		34.7	30.0	43.1	36.8	4,700	5,720
					Minimum		14.5	5.9	33.9	29.2	1,288	2,730

NORWAY PINE.

11	Minnesota	4"x7" to 6"x7"	30"	Partially air dry	Average	13	28.6	10.7	33	26	2,090	2,560
					Maximum		54.6	16.7	......	......	2,725	3,180
					Minimum		21.1	6.2	......	......	1,555	2,020
12	Minnesota	3½"x3½"	30"	Air dry	Average	63	14.9	13.5	31.2	27.2	3,350	4,320
					Maximum		19.6	33.0	39.3	34.0	5,360	6,700
					Minimum		13.1	4.5	25.5	21.4	1,460	2,400

TABLE 13.—*Compressive strength at elastic limit at right angles to grain.*

Reference No.	Locality of growth.	Dimensions. Width.	Dimensions. Height.	Dimensions. Length.	Width of plate.	Condition of seasoning.		Number of tests.	Moisture per cent.	Rings per inch.	Weight per cu. ft., oven dry.	Compressive strength at elastic limit.
	LOBLOLLY PINE.										*Lbs.*	*Lbs. per sq. in.*
1	South Carolina and Virginia	4″ to 8″	8″	24″ to 30″	4″	Green	Average	44	57.1	4.7	28	469
							Maximum		117.0	10.0	40	875
							Minimum		30.4	2.5	20	195
	LONGLEAF PINE.											
2	South Carolina	3″ to 4″	3″ to 4″	12″	4″	Partially air dry	Average	22	25.1	18.0	36	572
							Maximum		30.9	29.0	43	875
							Minimum		21.7	11.0	31	375
	DOUGLAS FIR.											
3	Oregon and Washington	3″ to 8″	4″ to 16″	19″ to 42″	4″	Partially air dry	Average	374	21.6	13.8	27.7	651
							Maximum		39.5	44.0	36.7	1,632
							Minimum		12.7	3.0	20.3	312
	WESTERN HEMLOCK.											
4	Oregon and Washington	3″ to 8″	3″ to 16″	13″ to 30″	4″	Partially air dry	Average	115	28.3	12.7	25.6	477
							Maximum		61.0	34.0	33.1	988
							Minimum		15.4	5.0	19.3	234

TABLE 14.—*Showing strength parallel to grain (small pieces).*

Reference No.	Locality of growth.	Area of sheared section.	Condition of seasoning.	Grade.	Number o ftests.	Moisture per cent.	Rings per inch.	Weight per cu. ft. oven dry.	Shearing strength.
				LOBLOLLY PINE.					
								Lbs.	*Lbs. per sq. in.*
1	South Carolina and Virginia	3.5"x2"	Green	Average	121	83.2	4.3	30	630
				Maximum		180.5	12.5	....	1,056
				Minimum		35.2	2.0	....	276
				LONGLEAF PINE.					
2	Georgia	3.5"x2"	Partially air dry	Average	44	21.8	20.0	36	973
				Maximum		39.4	39.0	48	1,257
				Minimum		18.2	8.0	31	800
				DOUGLAS FIR.					
3	Oregon and Washington	3.0"x1.5"	Partially air dry	Average	758	23.8	15.0	29.0	770
				Maximum		39.5	50.0	36.5	1,495
				Minimum		12.3	2.0	19.8	214
				WESTERN HEMLOCK.					
4	Oregon and Washington	3.0"x1.5"	Partially air dry	Average	196	30.3	12.4	26.3	746
				Maximum		70.0	34.0	35.5	1,180
				Minimum		18.3	5.0	20.3	371
				TAMARACK.					
5	Minnesota	1"x4" and 2"x4"	Green	Average	24	39.2	9.1	*31.1	668
				Maximum		54.9	27.0	....	840
				Minimum		25.1	4.0	....	461
				NORWAY PINE.					
6	Minnesota	1"x4" and 2"x4"	Partially air dry	Average	20	26.7	7.5	*25.4	589
				Maximum		35.0	15.0	....	768
				Minimum		21.7	5.0	....	476

* Oven-dry weight per cubic foot taken from main bending tests.

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The Lime-Sulphur-Salt Wash and Its Substitutes

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INTRODUCTION.

During the past two years the Miscellaneous Laboratory of the Bureau of Chemistry, at the request of the Bureau of Entomology, has made a number of studies of the composition and decomposition of the lime-sulphur-salt wash and its substitutes, and the results of these studies have appeared in various publications from time to time. Recently much more extended studies have been made, which, together with the earlier work, are presented in the present report. All of the experiments reported in this bulletin have a practical significance and were conducted with a view to solving certain problems arising in actual practice, questions concerning which are often asked by correspondents both of the Bureau of Entomology and the Bureau of Chemistry.

Messrs. B. H. Smith and Charles Goodrich, of the Bureau of Chemistry, assisted in the analytical work, and Messrs. C. L. Marlatt and A. L. Quaintance of the Bureau of Entomology, made many valuable suggestions in regard to the solution of the problems presented.

THE LIME-SULPHUR-SALT WASH.

EFFECT OF TIME OF BOILING ON COMPOSITION OF WASH.

The first experiment was to determine the composition of the lime-sulphur-salt wash, using constant amounts of the various ingredients but boiling for varying lengths of time, or, in other words, to study the effect of the time of boiling on the composition of the wash. For this purpose chemically pure reagents were employed, and a fractional part of the following formula used: Lime 30 pounds, sulphur 20 pounds, salt 15 pounds, and water 60 gallons, the boiling being carried on in a closed enamel boiler. After mixing the above ingredients, and before heating, the volume of the mixture was determined, and in every experiment thereafter, whatever the time of boiling and the consequent reduction in volume, the total volume

was made up to the volume as first determined, and aliquot portions taken for analysis. Theoretically each 100 cc of such a mixture as the above should contain 5.55 grams of calcium oxid and 3.89 grams of sulphur, in case there had been no loss by volatilization or mechanically.

METHODS OF EXAMINING THE TOTAL WASH.

The mixture was boiled for the required length of time, made up to the correct volume as determined above, thoroughly shaken and 100 cc portions taken for analysis. This portion was weighed, poured through a weighed Gooch, well exhausted, and the residue dried at 110° C., and weighed. The difference between the total weight of 100 cc of the mixture and the weight of the residue was taken to be the weight of the liquid portion in 100 cc of the mixture. An aliquot portion of the liquid portion was weighed to obtain the weight of 1 cc. The total weight of the liquid divided by the weight of 1 cc gives the number of cubic centimeters of liquid in 100 cc of the whole mixture. The soluble sulphur and calcium oxid were next determined in 1 to 5 cc of the liquid. The results obtained on 1 cc of the liquid multiplied by the number of cubic centimeters of the liquid in 100 cc of the mixture give the weight of the dissolved sulphur and calcium oxid in 100 cc of the original wash. The residual and volatile sulphur reckoned together and the residual calcium oxid were obtained by subtracting the soluble sulphur and calcium oxid from the theoretical total amount of sulphur and calcium oxid, respectively. The method used for determining the soluble calcium oxid was the oxalate method usually employed, so it needs no explanation. The Avery method* for determining soluble sulphur was used. The following results were obtained on five washes boiled for different lengths of time:

TABLE 1.—*Lime and sulphur in 100 cc of the lime-sulphur-salt wash boiled for varying periods.*

Time of boiling.[a]	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium oxid.	Total calcium oxid.
Minutes.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
15	3.03	0.86	3.89	1.64	3.91	5.55
30	3.66	.23	3.89	1.95	3.60	5.55
45	3.72	.17	3.89	1.93	3.62	5.55
60	3.75	.14	3.89	2.13	3.42	5.55
90	3.45	.42	3.89	1.85	3.70	5.55

[a] The mixture was brought to a boil before the time was taken.

*U. S. Dept. Agr., Bureau of Chemistry, Bul. 90, p. 105; Cir. 10, Rev., p. 10.

From the above table it would appear (1) that the solid sulphur was not completely dissolved by 15 minutes' boiling; (2) that a 30-minute period of boiling was not quite long enough; (3) that a 45 to 60-minute period of boiling dissolved practically all of the sulphur present, and is consequently the best length of time to boil the wash to get a maximum amount of sulphur in solution. By continuing the boiling beyond one hour the mixture became very thick, with the quantity of materials used, and probably some of the sulphur was lost mechanically.

An attempt was next made to determine what compounds of sulphur are found in this wash, and whether they are changed by varying the period of boiling. To do this the following methods of analysis were used:

METHOD OF EXAMINING THE LIQUID PORTION OF THE WASH.

Sulphur in solution as sulphids.—Pipette 25 cc of the liquid portion of the wash into a 100 cc flask and make up to the mark. Use 10 cc of this, representing 2.5 cc of the original solution, for analysis. Add an ammoniacal zinc chlorid solution (made by dissolving 3.253 grams of pure zinc in hydrochloric acid, supersaturating with ammonia, and making up to a liter) until slightly in excess, as shown by adding a drop of the solution to nickel sulphate. Place on the steam bath and heat until the odor of ammonia becomes faint, filter, and wash. Transfer filter and contents to a beaker, add about 10 to 15 cc of a saturated solution of potassium hydroxid, and heat for some time. Add 50 cc of hydrogen dioxid, free of sulphates, and heat on the steam bath exactly 30 minutes. Acidify with hydrochloric acid and precipitate with barium chlorid in the usual way.

Sulphur in solution as thiosulphates.—Pipette 5 cc of the original solution into a 50 cc flask and add ammoniacal zinc chlorid until it is slightly in excess, as shown by nickel sulphate. Make this mixture up to the mark, shake, and filter off through a dry filter. To a 25 cc aliquot of the filtrate add methyl orange and titrate with tenth-normal hydrochloric acid to exact neutrality. Next titrate the liquid with a tenth-normal iodin solution. The reading thus obtained gives the total thiosulphates and sulphites; since, however, the sulphites are present in such small amounts as to be negligible the number of cubic centimeters of iodin solution used may be considered to represent only the thiosulphates.

Sulphur as combined sulphates and sulphites.—Proceed as in the preceding method to the point where the thiosulphates have been

changed to tetrathionates, and sulphites to sulphates by the addition of tenth-normal iodin. Make slightly acid with hydrochloric acid and precipitate the combined sulphates and sulphites (now sulphates) with barium chlorid in the usual way.*

Working by these methods the following results were obtained on the liquid portion of the wash:

TABLE II.—*Sulphur compounds in 100 cc of the liquid portion of the lime-sulphur-salt wash boiled for varying periods.*

Time of boiling.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	Total sulphur.
Minutes.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
15	0.63	2.59	0.004	3.224
30	.76	2.91	.004	3.674
60	.84	2.91	.01	3.76
90	.86	2.92	.01	3.79

Three points are brought out by the above results: (1) A 1-hour period of boiling dissolves practically all of the sulphur; (2) the thiosulphates are somewhat increased by a more prolonged period of boiling; (3) the combined sulphates and sulphites are somewhat increased by a more prolonged period of boiling.

Reactions involved.—It is probable that the primary reaction in the combination of sulphur and lime which takes place is as follows:

(1) $$3Ca(OH)_2+12S=CaS_2O_3+2CaS_5+3H_2O$$

Such a reaction, however, would lead to the formation of less sulphur as thiosulphate and more sulphur as pentasulphid than is indicated in Table II. It is therefore probable that either one or both of the two following secondary reactions take place, both of which would lead to the formation of more thiosulphate and less polysulphid, thus approximating the figures in the table.

(2) $$3Ca(OH)_2+8S=CaS_2O_3+2CaS_3+3H_2O$$

(3) $$CaS_5+3O=CaS_2O_3+3S$$

The sulphur set free in this last reaction would on further boiling combine with more lime to form thiosulphate and polysulphid. If the boiling be continued, it will be seen that more thiosulphate

* This method of analysis and those that follow are combinations of Avery's method for determining sulphur with certain methods given in Sutton's Volumetric Analysis, modified to meet the conditions here presented.

would constantly be formed at the expense of the pentasulphid. Since the figures given indicate that more thiosulphate and less polysulphid are formed than is indicated by the first theoretical equation, it is probable that equation (3) is the principal or only secondary reaction leading to the formation of thiosulphate.

It is well known that thiosulphates in solution change slowly to sulphites, which in turn change to sulphates, according to the following reactions:

(4) $$CaS_2O_3=CaSO_3+S,$$

and

(5) $$CaSO_3+O=CaSO_4$$

It is therefore probable that sulphates and sulphites are found in the wash because of the above changes. The five reactions given are well known and can be found in any of the leading books of reference.* As would be expected, therefore, there are found in the lime-sulphur-salt wash comparatively large quantities of pentasulphid and thiosulphate and extremely small quantities of sulphates and sulphites.

EFFECT OF SODIUM CHLORID ON THE COMPOSITION OF THE WASH.

An experiment was next carried out to determine whether or not the sodium chlorid used had any influence upon the amount and relative quantities of the various sulphur compounds in the wash. The same formula was used as in the first experiment, and a 1-hour period of boiling employed for both the wash with salt and the wash without salt. The following results were obtained:

TABLE III.—*Sulphur compounds in 100 cc of the liquid portion of the wash with and without salt.*

Composition of the wash.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphites and sulphates.	Total sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Lime-salt-sulphur	0.84	2.91	0.01	3.76
Lime-sulphur	.88	2.92	....	3.80

It is evident from these results that salt has practically no influence upon the composition of the wash in so far as the sulphur compounds are concerned, and therefore the following experiments were performed without the addition of salt.

* Mendeleeff's Principles of Chemistry; Thorpe's Dictionary of Applied Chemistry; Fremy's Chemical Encyclopædia, etc.

EFFECT OF COMMERCIAL REAGENTS AND CHANGE OF FORMULA ON THE LIME-SULPHUR WASH.

To ascertain whether approximately the same time was required to get all sulphur in solution if high grade commercial reagents were employed instead of chemically pure ones, and also whether changing the formula from the one previously used to one commonly employed by orchardists had any influence upon the time necessary to get a maximum amount of sulphur in solution, another set of experiments was conducted. The formula used was as follows: Lime 20 pounds, sulphur 15 pounds, and water 50 gallons, good grades of commercial stone lime and sulphur being used. The results obtained are given in Tables IV and V.

TABLE IV.—*Lime and sulphur in 100 cc of lime-sulphur wash, using modified formula and commercial reagents.*

Time of boiling.	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium oxid.	Total calcium oxid.
Minutes.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
15	2.50	0.90	3.40	1.30	3.20	4.50
30	3.13	.27	3.40	1.69	2.81	4.50
45	3.19	.21	3.40	1.78	2.72	4.50
60	3.18	.22	3.40	1.88	2.62	4.50
120	3.19	.21	3.40	1.87	2.63	4.50

TABLE V.—*Sulphur compounds in 100 cc of the liquid portion of the lime-sulphur wash, using modified formula and commercial reagents.*

Time of boiling.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	Total sulphur.
Minutes.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
15	0.48	2.05	0.02	2.55
30	.63	2.54	.02	3.19
45	.68	2.54	.02	3.24
60	.69	2.52	.02	3.23
120	.74	2.50	.02	3.26

From these results it is evident (1) that the solid sulphur was not completely dissolved by 15 minutes' boiling; (2) that a 30-minute period of boiling was not quite sufficient; (3) that a 45 to 60 minute period of boiling dissolved practically all the sulphur; (4) that the thiosulphates were somewhat increased by a more prolonged period of boiling. Since these are exactly the same as the conclusions reached in the first experiment, it is evident that a slight change in formula has no influence upon the time of boiling necessary to dis-

solve all the sulphur, nor has a substitution of high grade commercial lime and sulphur for the chemically pure articles any influence upon the same point.

LIME-SULPHUR WASHES PREPARED ACCORDING TO DIFFERENT FORMULAS.

The next set of experiments was to determine the composition of lime-sulphur mixtures boiled the same length of time (one hour), but containing varying quantities of lime and sulphur. Fractional parts of the following formulas were used in preparing the mixtures.

TABLE VI.—*Various formulas used in preparing experimental lime-sulphur washe*

Number of experiment.	Sulphur.	Lime.	Water.
	Pounds.	*Pounds.*	*Gallons.*
1	25	30	50
2	25	20	50
3	15	25	50
4	15	20	50
5	15	15	50

The results obtained on the five different washes described in Table VI are given in Tables VII and VIII.

TABLE VII.—*Lime and sulphur in 100 cc of five lime-sulphur washes of varying composition.*

Number of experiment.	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium oxid.	Total calcium oxid.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
1	5.22	0.48	5.70	2.89	3.91	6.80
2	5.30	.40	5.70	2.76	1.74	4.50
3	3.20	.20	3.40	1.80	3.90	5.70
4	3.17	.23	3.40	1.76	2.74	4.50
5	3.17	.23	3.40	1.73	1.67	3.40

TABLE VIII.—*Sulphur compound in 100 cc of the liquid portion of fine lime-sulphur washes of varying composition.*

Number of experiment.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphites and sulphates.	Total sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
1	1.08	4.26	0.02	5.36
2	.99	4.34	.02	5.35
3	.69	2.53	.01	3.23
4	.67	2.53	.01	3.21
5	.66	2.53	.01	3.20

From these results the following conclusions are drawn:

(1) The proportion of one part of lime to one of sulphur gives more than enough lime to dissolve the maximum amount of sulphur. (Experiment 5.)

(2) If more lime than the amount first mentioned is added in proportion to the sulphur it only remains present as so much excess lime nad does not aid in the solution of more sulphur. (Experiments 3, 4, 5.)

(3) With a constant amount of sulphur present and varying amounts of lime, not only is the total sulphur practically constant but the various sulphur compounds present are the same. (Experiments 3, 4, 5.)

(4) Twenty-five pounds of sulphur per 50 gallons is about the maximum quantity, or a little more than the maximum quantity, that can be dissolved. This fact is shown, not only by the residual sulphur being present in considerable quantities in the two formulas where 25 pounds of sulphur were used (experiments 1 and 2), but also by the fact that in both of these cases when the wash cooled down to room temperature needles of an orange color, evidently a sulphur compound, crystallized out.

(5) It would also appear from experiment 2 that sufficient lime is present when it is used in the proportion of 1 part of lime to 1¼ parts of sulphur, but the experiment on this point is marred by the fact that in this formula as much or a little more sulphur is present than can go into solution in the amount of water used. According to the theoretical reaction one could use almost twice as much sulphur as lime and yet get all the sulphur in solution. It is extremely doubtful, however, whether the reaction would completely take place under these circumstances or whether, if it did so, it would not require an exceedingly long period of boiling. In addition to these considerations, in practice a moderate excess of lime is needed to exert its caustic action on the scale.

Taking all of these points into consideration it would appear, on purely theoretical grounds, that approximately the following formula should be used to obtain, at a minimum cost, a wash with the maximum amount of sulphur in solution and a moderate excess of lime, namely—water 50 gallons, lime 20 to 22.5 pounds, sulphur 22.5 pounds. Whether or not this formula would give the best results in actual orchard practice is a subject for experimentation.

LIME-SULPHUR WASHES PREPARED WITH DIFFERENT KINDS OF LIME.

Experiments were next conducted to determine what effect the use of air-slaked lime instead of quicklime would have on the composition of a wash prepared according to one of the common formulas. For this purpose the formula, lime 20 pounds, sulphur 15 pounds, water 50 gallons, with a 1-hour period of boiling, was used. The air-slaked lime employed had not of course been left in the air a sufficient length of time to entirely change to carbonate but was merely the powder left after stone lime had fully slaked in the open air. The results obtained are given in Tables IX and X.

TABLE IX.—*Lime and sulphur in 100 cc of lime-sulphur wash, using air-slaked and quicklime.*

Kind of lime.	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Quicklime	3.18	0.22	3.40	1.88
Air-slaked	3.26	.14	3.40	1.62

TABLE X.—*Sulphur compounds in 100 cc of the liquid portion of lime-sulphur wash, using air-slaked and quicklime.*

Kind of lime.	Sulphur as thiosulphate.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	Total sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Quicklime	0.69	2.52	0.02	3.23
Air-slaked	.68	2.60	.02	3.30

From these figures it is evident that the employment of moderately air-slaked lime has practically no influence on the composition of the wash. The sulphur compounds formed are nearly the same in amount as when quicklime is used, but the amount of lime in solution appears to be slightly larger when quicklime is employed. The writer is more inclined to ascribe this slight difference in the amount of dissolved lime to slight errors in the analysis than to any real difference. It is self-evident that if the air-slaked lime were left in the air long enough to become wholly changed to carbonate it could not be used to prepare the wash.

LIME-SULPHUR WASHES PREPARED WITH THE HEAT GENERATED BY QUICKLIME.

In this experiment, to determine whether a lime-sulphur wash could be prepared with no external heat, using only the heat generated by slaking the lime, a constant amount of sulphur was used and varying amounts of lime. The wash so obtained was then compared with a wash prepared by the same formula, but boiled until the maximum amount of sulphur had dissolved. Following are the formulas used and the results obtained:

TABLE XI.—*Formulas used for preparing lime-sulphur washes.*

Number of experiment.	Lime.	Sulphur.	Water.	Time of heating.
	Pounds.	*Pounds.*	*Gallons.*	*Hours.*
1	40	15	50	0
2	30	15	50	0
3	30	15	50	1

TABLE XII.—*Lime and sulphur in 100 cc of lime-sulphur washes prepared by boiling and with the heat of slaking lime.*

Number of experiment.	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium oxid.	Total calcium oxid.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
1	0.25	3.15	3.40	0.23	8.77	9.00
2	.19	3.21	3.40	.20	6.60	6.80
3 (Boiled)	3.16	.24	3 40	1.74	5.06	6.80

TABLE XIII.—*Sulphur compounds in 100 cc of the liquid portion of lime-sulphur washes prepared by boiling and with the heat of slaking lime.*

Number of experiment.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	Total sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
1	0.04	0.21	0.02	0.27
2	.03	.15	.02	.20
3 (Boiled)	.71	2.50	.03	3.24

From these experiments it is evident that a satisfactory wash can not be made with the heat generated by slaking lime, not even if a large excess of lime is used so that a maximum amount of heat will be generated.

LIME-SULPHUR WASHES PREPARED WITH DIFFERENT FORMS OF SULPHUR.

In this experiment, to determine the effect of the form of sulphur used on the composition of the wash, the following formula was employed and the boiling continued for 1 hour: lime 20 pounds, sulphur 15 pounds, water 50 gallons. Three forms of sulphur were used, namely, flowers of sulphur, flour sulphur, and another form known in the South as crystallized sulphur. The last-named form of sulphur comes from Louisiana and is obtained from the ore by melting out the sulphur and allowing it to solidify as brimstone. It is then shipped in lumps as it breaks under the pick. It presents smooth, hard, crystalline surfaces to view. The following results were obtained:

TABLE XIV.—*Lime and sulphur in 100 cc of lime-sulphur washes prepared with different forms of sulphur.*

Form of sulphur used	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium oxid.	Total calcium oxid.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Flowers	3.17	0.28	3.40	1.76	2.74	4.50
Flour	3.30	.10	3.40	1.81	2.69	4.50
Crystalline	3.03	.34	3 40	1.51	2.99	4.50
	1.36	2.04	3.40	.70	3 80	4.50

TABLE XV.—*Sulphur compounds in 100 cc of the liquid portion of lime-sulphur washes prepared with different forms of sulphur.*

Form of sulphur used.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	Total sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Flowers	0.68	2.55	0.02	3.25
Flour	.68	2.67	.02	3.37
Crystalline	.58	2.53	.01	3.12
	.27	1.11	.01	1.39

It is evident from these analyses that there is practically no difference in the washes prepared with flowers of sulphur and flour sulphur, and that crystalline sulphur gives a wash of extremely variable composition, depending, no doubt, on the size of the particles of sulphur used and the time of boiling.

LIME-SULPHUR WASHES PREPARED WITH GROUND CRYSTALLINE SULPHUR.

Since the preceding experiment showed that the crystalline sulphur when used without powdering gave a wash of extremely variable composition, the following experiment was planned to determine what kind of a wash this form of sulphur would give if it were finely powdered, and how long it was necessary to boil the powdered crystalline sulphur to get all of the sulphur in solution.

The same formulas were used as described in the preceding experiment, but the sulphur was ground and boiled in the first experiment for 1½ hours, and in the second for 2 hours. The following results were obtained:

TABLE XVI.—*Lime and sulphur in 100 cc of the lime-sulphur wash, using ground crystalline sulphur.*

Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium oxid.	Total calcium oxid.	Time of boiling.
Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Hours.*
3.04	0.36	3.40	1.76	2.74	4.50	1½
3.13	.27	3.40	1.80	2.70	4.50	2

TABLE XVII.—*Sulphur compounds in 100 cc of the liquid portion of the lime-sulphur wash, using ground crystalline sulphur.*

Sulphur as thiosulphate.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	Total sulphur.	Time of boiling.
Grams.	*Grams.*	*Grams.*	*Grams.*	*Hours.*
0.65	2.44	0.01	3.10	1½
.70	2.48	.01	3.19	2

From these figures it is evident that even if the crystallized sulphur is ground to quite a fine powder it is in such a form that it dissolves more slowly than the flowers of sulphur or the flour sulphur. It also appears that with the ground crystalline sulphur about 2 hours' boiling is necessary to get the maximum amount of sulphur in solution. This increased time necessary to dissolve the crystalline sulphur is evidently due to its physical characteristics.

COLOR OF THE LIME-SULPHUR WASH.

Before leaving the consideration of the composition of the lime-sulphur-salt or the lime-sulphur wash, a word in regard to the correct color of the wash may be of value. The writer has seen many different statements in regard to this matter. Some claim

that the wash when finally prepared should be yellow, some golden, some orange, some brown, and some olive green.

To test the color a wash was prepared with chemically pure lime and sulphur, boiling until all sulphur had dissolved. It was found that the color of the supernatant liquid was almost exactly the same as that of the skin of a dark, rusty-coated orange. When the mixture was stirred so that the white lime was evenly distributed throughout the solution, the color was much lighter. With most grades of commercial lime the colors of the supernatant liquid and of the total mixture were as just described; in the case of a few limes that came under the writer's observation, however, it was observed that the mixture when finally prepared was an olive green. On allowing the mixture to settle, the supernatant liquid was orange just as one would expect it to be, but the lime at the bottom was a deep olive green. It is therefore evident that the olive-green color of the mixture noted by some observers is due to impurities in the lime—probably compounds formed by the action of the sulphids of the wash on iron and manganese in the lime.

DECOMPOSITION OF THE LIME-SULPHUR-SALT WASH ON TREES.

An attempt was next made to determine what changes take place in the sulphur compounds of the wash when it is sprayed upon the tree. To imitate as closely as possible actual spraying conditions, measured samples of the filtered wash, 5 cc usually, were absorbed by a large quantity of filter paper, which had been cut in slips and placed in large porcelain dishes. These dishes were immediately put in the open air in direct sunlight and the paper allowed to dry. This usually took about one hour. The dishes were then placed in a protected place in the open air and allowed to stand for varying lengths of time. In one series of experiments the paper was moistened each morning to simulate the effect of dew; in another series it was allowed to remain undisturbed until analyzed.

From the studies already made of the composition of the wash, the following changes would be expected when the paper was allowed to dry in the open air: (1) The pentasulphid would be oxidized to thiosulphate and sulphur according to the equation: $CaS_5+O_3=CaS_2O_3+S_3$. This would result in the formation of more thiosulphate than was already present, and the deposition of free sulphur in a very finely divided form. (2) The total thiosulphate would then be changed to some extent to sulphite and deposit free sulphur, i. e.: $CaS_2O_3=CaSO_3+S$. (3) The sulphite would then be partially oxidized to sulphate according to the equation: $CaSO_3+$

$O=CaSO_4$. Finally, then, we would expect to find in the wash after it had dried on the tree, free sulphur, calcium triosulphate, and small quantities of calcium sulphate and sulphite. The longer the action of the air and the dew continued, the less calcium thiosulphates we would expect to find present and the more sulphites and sulphates. Of course calcium hydroxid would be present, which would gradually be changed to calcium carbonate. Sodium chlorid, in case it were used, appears to have no influence on the composition of the wash and would very likely remain as such on the tree.

To experimentally prove or disprove the above assumptions, a wash was prepared by boiling the following constituents together for one hour: Lime 30 pounds, sulphur 20 pounds, and water 50 gallons. The composition of 100 cc of the liquid portion of this wash was found to be as follows:

	Grams per 100 cc.
Sulphur as thiosulphates	0.85
Sulphur as polysulphids and sulphids	2.93
Sulphur as sulphates and sulphites	.02
Total	3.80

METHODS OF EXAMINING THE DECOMPOSED WASH.

The following methods were used to determine the composition of the wash after drying on filter paper.

Total free sulphur.—Extract the filter paper in a Soxhlet extractor with redistilled carbon bisulphid, evaporate the carbon bisulphid, dissolve the residual sulphur in concentrated potassium hydroxid by boiling, and determine the sulphur as sulphate according to the Avery method. Allow the filter paper remaining from the above treatment to stand till all the carbon bisulphid has evaporated, then beat it to a pulp with water and transfer the mass to a Gooch filter. Continue the extraction with water till the washings amount to about 450 cc of water, and determine the soluble sulphur compounds present in this filtrate. Repeat the washing with 450 cc of water several times, or until all the soluble sulphur compounds are extracted, and determine the sulphur compounds in the filtrates. Analyze the successive 450 portions of filtrate (sometimes amounting to three in number and even to six before all the soluble sulphur compounds are extracted) and add the results obtained, to get the total sulphur content in its variable soluble forms.

Sulphur as sulphids.—Remove a few drops of the first filtrate and test qualitatively for sulphids and polysulphids. (Neither

were found in the experiments reported.) Then analyze each 450 cc filtrate by the following methods: Add methyl orange and titrate the solution with tenth-normal hydrochloric acid to exact neutrality. Make up the volume to the 500 cc mark.

Sulphur as sulphates and sulphites.—Titrate a 250 cc portion of each of the above filtrates with iodin solution till the brown color of the iodin appears. Add a little more hydrochloric acid, boil the solution, precipitate with barium chlorid in the usual manner, and finally weigh as barium sulphate. (By this method the thiosulphate is changed to tetrathionate and the sulphite to sulphate, so that sulphates and sulphites are determined together as sulphates. The weak point in this determination is the fact that the tetrathionate seems to decompose to a *very slight extent* in boiling with hydrochloric acid, thus forming sulphate.)

Sulphur as sulphites and thiosulphates.—Measure off in a beaker a known volume of tenth-normal iodin (about 4 cc for the first filtrate and 0.2 to 0.3 cc for the subsequent filtrates), add water and as much of the 250 cc of the neutral filtrate left above titrated against the iodins as is necessary to arrive at the end point, using starch as indicator. This figure represents the sulphite and thiosulphate in a known volume of the 500 cc filtrate, and can be calculated back to the amount of iodin necessary for the whole filtrate. The solution was titrated against the iodin rather than the iodin against the solution, because it has been found by many investigators that more constant results are obtained in this way.

Sulphur as sulphites.—To the solution in a known quantity of which the sulphites and thiosulphates have been determined, as above, by means of tenth-normal iodin, add a little methyl orange and titrate to neutrality with tenth-normal sodium hydroxid. From this figure calculate the sulphite present in the whole 500 cc filtrate. This method of analysis is based on the following principle: When athiosulphate is changed to a tetrathionate by iodin, there is no change in the reaction of the solution, because both the thiosulphate and tetrathionate are neutral. When a bisulphite which is neutral to methyl orange is oxydized, however, by iodin to bisulphate, the solution becomes acid, both from the hydriodic acid set free and the bisulphate formed, and the combined quantity of these two, as determined by tenth-normal sodium hydroxid, is a measure of the sulphite present. In the above analysis all sulphites were changed to bisulphites by the original titration of the solution with tenth-normal hydrochloric acid to neutrality.*

* A discussion of these methods of analysis is given on page 353 of the 8th edition of Sutton's Volumetric Analysis.

Sulphur as sulphates.—Subtract the sulphur as sulphites from the total sulphur as sulphates and sulphites.

Sulphur as thiosulphates.—Subtract from the total iodin figure obtained for thiosulphates and sulphites an amount of iodin corresponding to the sulphites as determined above and calculate the resulting iodin to thiosulphates.

Following are the results obtained on allowing four samples of the wash to stand in the open air for varying periods of time, after being absorbed by slips of filter paper.

TABLE XVIII.—*Composition of dry lime-sulphur-salt wash after standing.*

[Expressed in grams per 100 cc of solution.]

SAMPLES NOT WATERED.

Time of standing.	Free sulphur.	Sulphur as thiosulphates.	Sulphur as sulphites.	Sulphur as sulphates.	Total sulphur.
(a) 5 days	1.71	1.97	0.11	0.01	3.80
(b) 5 days	1.72	1.97	.10	.01	3.80
(c) 8 days	1.74	1.94	.137	.01	3.83
(d) 8 days	1.77	1.94	.12	.02	3.85

SAMPLES WATERED TO SIMULATE DEW.

Time of standing.	Free sulphur.	Sulphur as thiosulphates.	Sulphur as sulphites.	Sulphur as sulphates.	Total sulphur.
(e) 10 days	1.94	1.66	0.22	....	3.82
(f) 10 days	1.93	1.69	.20	....	3.82
(g) 4 weeks	2.11	1.42	.29	0.15	a3.97
(h) 4 weeks	2.13	1.41	.27	.16	a3.97

* The rather high results obtained for total sulphur in these two determinations is doubtless owing to errors in analysis, especially in the thiosulphate figures. The method of analysis outlined above is very difficult of execution, even under the best circumstances. In these two determinations six extractions of 500 cc each were necessary to extract all soluble sulphur compounds. This resulted in very small amounts of material being present in the last four 500 cc filtrates, and consequently the chances of error in the determinations were increased

From Table XVIII it is evident that just those changes take place in the wash when it dries on the tree that the theoretical equations would lead one to expect. Analyses (a) and (b), after 5 days, indicate that the following reaction has taken place: (1) $CaS_5+O_3=CaS_2O_3+3S$, resulting in a deposition of sulphur and an increased formation of calcium thiosulphate. These two analyses also indicate that the following reaction has begun: (2) $CaS_2O_3=CaSO_3+S$, resulting in the formation of more calcium sulphite and more free sulphur.

Analyses (c) and (d), after 8 days, indicate that the reaction shown above as (2) has gone still further and that the following reaction has commenced—(3) $CaSO_3+O=CaSO_4$—resulting in the formation of more calcium sulphate. Analyses (e) and (f), after

10 days, indicate that the rapidity of reactions (2) and (3) has been much increased by wetting the paper every day or in practice by the wetting of the branches every day by the dew.

Analyses (g) and (h), after 4 weeks, indicate that the above reactions (2) and (3) have gone still further, resulting in the breaking up of about one-fourth of the thiosulphate and the consequent increase in free sulphur, sulphates, and sulphites. If the decomposotion of the wash continued at the same rate as is indicated above, it would take it about four or five months to completely decompose, at least under these artificial conditions. When the decomposition of the thiosulphate was complete a very large amount of free sulphur would still be upon the tree; calcium sulphate and calcium sulphite would also be present. Still later the sulphite would be oxidized to sulphate, so that finally only free sulphur and calcium sulphate would be present, after perhaps four to six months. In case of a very hot sun shining upon the tree the sulphur itself might be volatilized, leaving only calcium sulphate.

THEORY OF THE ACTION OF THE WASH ON INSECTS.

From the above data a theory can be formed in regard to the action of this wash. First, consider a case in which the wash, after being sprayed upon the tree, remains practically untouched by rains for several months, as in the dry climate of California, so that the products of decomposition remain on the tree a long time. First, the excess of lime in the wash is quite caustic, and thus loosens the scales from the tree and exposes the insects. Almost at once the pentasulphid, on decomposing, deposits sulphur in a very finely divided condition, which has its usual insecticidal value, but just how this is exerted is not known. The thiosulphate present in the wash, together with that formed by the decomposition of the pentasulphid, probably has some insecticidal properties also. Next the thiosulphate begins to decompose and sets free sulphite and more free sulphur. This decomposition of the thiosulphate probably extends over several months. It is a well-known fact that sulphites act as antiseptic agents. There is reason to believe that they would also act as insecticides. From the decomposition of the wash there are obtained sulphur in a very finely divided form, thiosulphate for a time, and sulphite which is gradually set free. The writer is of the opinion that these are the active agents in killing insects. This theory of the action of the wash would also explain why it continues to be efficacious over a considerable length of time.

In a wet climate, on the other hand, if a heavy rain should occur a day or two after the wash was applied, all the thiosulphate which was originally present, together with that which had been formed by the decompositon of the pentasulphid would probably be washed away. No sulphite could then be formed by slow decomposition of the thiosulphate. There would, therefore, be left upon the tree free sulphur as the only compound having insecticidal properties. The efficacy of the wash would, therefore, be much reduced. Again, if light rains occurred occasionally after the wash had been applied, its efficacy would be reduced just in proportion to the amount of thiosulphate and sulphite washed away.

It has been suggested by Mr. F. H. Pough, manager of the Bergen Port Sulphur Works of New York City, that the efficiency of the lime-sulphur-salt wash was due almost entirely to the finely divided sulphur set free on the decomposition of the pentasulphid. In support of this the widespread use of sulphur as a fungicide and insecticide was cited, more particularly its use for the prevention of the powdery mildew in vineyards, where it is often sprinkled on the hot ground to the windward of the plants, as well as on them; also to the value of sulphur dusting to destroy the red spider of citrus trees.

It is believed by Mr. Pough that the action of the wash is to be attributed to the gradual oxidation of sulphur which gives rise to sulphur dioxid, or sulphurous acid, where moisture is present, and that it is these constituents that do the work. In support of this theory he cites the cases where an odor resembling sulphur dioxid is plainly discernible on hot sunny days in the vicinity of orchards sprayed with the above mixture.

While the writer does believe that finely divided sulphur is one of the active insecticidal agents in the wash, though just how it acts is not known, he is inclined to doubt very much whether this oxidation of the sulphur alone would be rapid enough to be of great value. The following points are against this theory:

(1) If the action were at all considerable, it would be expected that the total sulphur on the tree would decrease, since not all the sulphur dioxid formed would be likely to be absorbed by the calcium hydroxid or calcium carbonate present, these being only mechanically mixed with the sulphur. In the "paper experiments," which to be sure are artificial, no loss of sulphur was shown after four weeks.

(2) It would be expected that the free sulphur would decrease during the course of four weeks by conversion to sulphur dioxid;

instead of this, it increases to a slightly greater extent than corresponds to the amount of sulphur formed from the breaking up of thiosulphate, according to the following equation:

$$CaS_2O_3 = CaSO_3 + S$$

(3) In regard to the odor resembling that of sulphur dioxid observed by Mr. Pough, those who have sublimed sulphur know that during sublimation this odor is very noticeable, so that the odor noticed in the vicinity of orchards on a hot sunny day may be due to subliming sulphur.

On the whole, while it is believed that some of the finely divided sulphur is oxidized, it seems doubtful whether enough is oxidized to make this factor a major one in determining the efficiency of the wash. It seems more probable that the combined action of all the sulphur compounds present, exclusive of the sulphate, gives to the wash its value.

THE LIME-SULPHUR-SALT-SODA WASH.

Having completed the study of the lime-sulphur-salt wash and the lime-sulphur wash prepared by various formulas and under different conditions, experiments were next undertaken along similar lines with the lime-sulphur-salt-soda and the lime-sulphur-soda washes. These washes have been suggested as substitutes for the older wash, without the soda, since it is said they can be prepared without any or with a minimum amount of boiling, thus saving the farmer much time and trouble.

LIME-SULPHUR-SALT-SODA WASH PREPARED WITHOUT EXTERNAL HEAT.

The first experiment was to determine the composition of a lime-sulphur-salt-soda wash prepared without external heat and compare it with that of a lime-sulphur-salt wash containing the same amounts of lime, sulphur, salt, and water, but boiled until the maximum amount of sulphur was dissolved. The following formulas and methods of procedure were followed, using chemically pure reagents:

For the lime-sulphur-salt-soda wash 30 pounds of lime, 20 pounds of sulphur, 15 pounds of salt, 10 pounds of caustic soda, and 60 gallons of water were used, and for the lime-sulphur-salt wash the same formula was employed exclusive of the caustic soda. The sulphur was made into a thin paste with 9 quarts of hot water, the lime slaked with 9 gallons of hot water, and the sulphur paste added to it. Then the caustic soda was stirred in and the mixture

boiled of itself for a considerable period. Salt was then added and the requisite amount of water to make up 60 gallons plus the space occupied by the solids, as determined by previous tests in the experiments with the lime-sulphur-salt wash. The lime-sulphur-salt wash was prepared by simply boiling the constituents together and making up to volume as in the previous experiments. The results given in Table XIX were obtained:

TABLE XIX.—*Lime and sulphur in 100 cc of the lime-sulphur-salt-soda wash.**

Constituents.	Sulphur in solution.	Residual and volatile sulphur	Total sulphur.	Calcium oxid in solution.	Residual calcium oxid.	Total calcium oxid.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Lime-sulphur-salt-soda	3.25	0.64	3.89	0.73	4.82	5.55
Lime-sulphur-salt	3.75	0.14	3.89	2.13	3.42	5.55

* The various sulphur compounds present in this mixture were not determined.

It is evident from these data that all of the sulphur is not dissolved by the heat generated by the caustic soda, and, further, that the sulphur that does go into solution does so to a great extent as the sodium, instead of the calcium, salts of the sulphur acids, thus causing a smaller amount of calcium oxid to be dissolved and a larger amount to remain as a residue than in the case of the lime-sulphur-salt mixture.

LIME-SULPHUR-SALT-SODA WASH PREPARED BY HEATING FOR A SHORT PERIOD.

Since the preceding experiment showed that the method of preparation of the lime-sulphur-salt-soda wash, without the aid of heat, did not dissolve all the sulphur, another experiment was made to determine whether the maximum amount of sulphur would be dissolved by heating for a very short period. The following results were obtained using chemically pure reagents, the same formulas as in the preceding case, and a 20-minute period of heating, that being the time necessary to bring the mixture from room temperature up to the boiling point.

TABLE XX.—*Lime and sulphur in 100 cc of the wash prepared with 20 minutes' heating.*

Constituents.	Time of heating.	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium.	Total calcium.
	Minutes.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Lime-sulphur-salt-soda*	20	3.79	0.10	3.89	0.75	4.80	5.55
Lime-sulphur-salt†	60	3.75	.14	3.89	2.13	3.42	5.55

TABLE XXI.—*Sulphur compounds in 100 cc of the liquid portion of the wash prepared with 20 minutes' heating.*

Constituents.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	Total sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Lime-sulphur-salt-soda*	0.88	3.04	0.005	3.925
Lime-salt-sulphur†	.84	2.91	.010	3.760

* Twenty minutes to bring to boil.
† Sixty minutes' boiling.

The following facts are indicated by Tables XX and XXI: (1) Practically all of the sulphur goes into solution in the lime-sulphur-salt-soda wash when it is heated for 20 minutes. (2) This treatment seems to dissolve a little more sulphur than by boiling with lime and salt for one hour. (3) The liquid portion of the lime-sulphur-salt-soda wash prepared as above contains the same sulphur acids in nearly the same amounts as the lime-sulphur-salt mixture, the only difference being that the sulphur compounds are present to a large extent as the sodium, instead of the calcium, salts. (4) More residual calcium oxid is present in the lime-sulphur-salt-soda wash than in the lime-sulphur-salt wash. (5) The former wash should be more caustic than the latter, both on account of the caustic soda present and also because of the greater excess of lime.

LIME-SULPHUR-SODA WASHES PREPARED WITHOUT EXTERNAL HEAT AND BY ADDING CONSTITUENTS IN DIFFERENT ORDERS.

The next experiment was for the purpose of determining how much sulphur goes into solution when high grade *commercial* sulphur, stone lime, and caustic soda are used instead of the chemically pure articles, and what influence the order in which these ingredients are added has on the composition of the wash. For this purpose a wash was first prepared according to the following formula: Lime, 30 pounds; sulphur, 15 pounds; water, 50 gallons, boiling for one hour and using high grade commercial ingredients. This wash was used as the standard and another wash was prepared, using the same amount of ingredients with the addition of 6 pounds of caustic soda to generate the heat and form a good medium for dissolving the sulphur. The following procedure was followed in the preparation of the second wash: The sulphur was made into a thin paste with hot water and added to the slaking lime. When the lime had ceased to slake, the full amount of caustic soda was added and the mixture stirred for 15 minutes. Water was

then added to make up to 50 gallons plus the space occupied by the solid reagents. This wash is designated as experiment 2.

In another sample of wash the same formula was used, but the order in which the ingredients were added was different, i. e., the sulphur was made in the form of a thin paste with hot water and the total caustic soda then added. The mixture was stirred for 15 minutes and the lime added and allowed to slake; water was then added to make up to 50 gallons plus the space occupied by the solid reagents. The mixture so made is designated as experiment 3.

The following results were obtained with these three washes:

TABLE XXII.—*Lime and sulphur in 100 cc of washes differently prepared.*

Number of experiment.	Ingredients.	Sulphur in solution.	Residual and volatile sulphur.	Total sulphur.	Calcium oxid in solution.	Residual calcium.	Total calcium.
		Grams.	*Grams*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
1	Lime-sulphur	3.16	0.24	3.40	1.74	5.06	6.80
2	Lime-sulphur-soda	2.27	1.13	3.40	.24	6.56	6.80
3	Sulphur-soda-lime	2.80	.60	3.40	.43	6.37	6.80

TABLE XXIII.—*Sulphur compounds in 100 cc of the liquid portions of washes differently prepared.*

Number of experiment.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphates and sulphites.	sulphur. sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
1	0.71	2.50	0.03	3.24
2	.41	1.91	.02	2.34
3	.47	2.37	.02	2.86

From these tables it is evident that high grade commercial samples of lime, sulphur, and soda, when used to prepare the lime-sulphur-soda wash, act practically the same as the chemically pure articles, resulting in the formation of a mixture containing about the same relative quantities of soluble sulphur compounds, though the amounts are decidedly smaller than those dissolved by boiling. Further, a better wash, i. e., one containing more sulphur in solution, is obtained by adding the ingredients in the order—sulphur, caustic soda, lime—than by mixing in the following order—lime, sulphur, caustic soda.

COMPARISON OF THE LIME-SULPHUR-SODA AND THE SULPHUR-SODA WASHES PREPARED WITHOUT EXTERNAL HEAT.

A comparison was next made of the composition of two washes, the first of which was prepared according to the following formula: Lime 30 pounds, sulphur 15 pounds, water 50 gallons, caustic soda 6 pounds, adding the constituents in the order—sulphur, caustic soda, lime—just as described in the preceding experiment. The second of the washes was prepared in the same way and by the same formula except that no lime was used. To make the comparison it was only necessary to examine the liquid portions of the washes. The following results were obtained, using high grade commercial ingredients:

TABLE XXIV.—*Sulphur compounds in 100 cc of the liquid portion of two washes prepared without external heat.*

Ingredients.	Sulphur as thiosulphates.	Sulphur as sulphids and polysulphids.	Sulphur as sulphites and sulphates.	Total sulphur.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Lime-sulphur-soda	0.47	2.37	0.02	2.86
Sulphur-soda	.35	1.59	.03	1.97

From this study it will be seen that more sulphur goes in solution in the lime-sulphur-soda wash prepared as above than when the same amounts of sulphur and soda are used, but no lime; also that the sulphur-soda wash contains the same sulphur acids as the lime-sulphur-salt and the lime-sulphur-soda mixtures, the only difference being that a smaller amount of the sulphur is dissolved than in either of the above-named washes, and that the sulphur acids are present only as sodium salts instead of wholly or partially as calcium salts.

DECOMPOSITION OF THE LIME-SULPHUR-SALT-SODA WASH ON TREES.

A study was next made of the decomposition of the lime-sulphur-salt-soda wash along the same lines that were followed for the lime-sulphur-salt wash. For this purpose a wash of the following formula was used: Lime 30 pounds, sulphur 20 pounds, salt 15 pounds, caustic soda 10 pounds, and water 60 gallons. The mixture was heated 20 minutes to dissolve all of the sulphur. When finally prepared the sulphur compounds in the liquid portion of the wash were found to be as follows, chemically pure reagents being used:

	Grams per 100 cc.
Sulphur as thiosulphates	0.88
Sulphur as polysulphids and sulphids	3.04
Sulphur as sulphates and sulphites	.005
Total sulphur	3.925

Portions of this wash were dried on filter paper, as already described under decomposition of the lime-sulphur-salt wash, and analyses of the same were made from time to time, with the following results:

TABLE XXV.—*Composition of the lime-sulphpr-salt-soda wash after drying.*

[Expressed in grams per 100 cc of solution.]

Time of standing.	Free sulphur.	Sulphur as thiosulphates.	Sulphur as sulphites.	Sulphur as sulphates.	Total sulphur.
Days.					
9*	1.57	2.27	0.02	0.00	3.86
28*	1.64	2.14	.06	.02	3.86
12*	1.64	2.19	.04	.01	3.88
27†	1.74	1.88	.10	.02	3.74

* Not watered to represent dew.
† Watered to represent dew.

From these data it is evident that the lime-sulphur-salt-soda wash decomposes in the same manner as the lime-sulphur-salt wash except that the rate of decomposition is much slower. Such being the case, it would appear, on purely chemical grounds, that the wash with caustic soda added ought to give just as good results as the original lime-sulphur-salt wash, if prepared so as to contain a like amount of sulphur. In fact, better results might be expected, since the sodium hydroxid is more caustic than the lime and would therefore tend to loosen the scale better, so that the other ingredients of the wash could act more thoroughly. However, two points must be taken into consideration: (1) the sodium sulphite, which is slowly formed, is more soluble than calcium sulphite, so that in a damp climate it would be washed off more easily; (2) that the rate of decomposition of the lime-sulphur-salt-soda wash is slower than that of the lime-sulphur-salt wash, and therefore it is possible that such decomposition might not take place rapidly enough to make it as efficacious as the old wash, assuming, of course, that the products formed by the gradual and slow decomposition have insecticidal properties. In expressing the above opinions the writer does so purely on the analytical data obtained in these studies, and of

course recognizes that field experiments are necessary to establish the truth or falsity of these conjectures.

PROPOSED NEW WASHES.

In the lime-sulphur-salt-soda wash the author is unable to see that anything is gained by the addition of salt, although it is recognized that some hold strenuously to the belief that the wash without it is a failure. Besides this it would appear that the caustic soda entirely takes the place of the lime, in so far as the caustic action of the wash on the scale is concerned. This is especially true in a dry climate where the caustic soda, which is much more soluble than the calcium hydroxid, is not washed off of the tree by rains. Therefore a wash composed only of sulphur, caustic soda, and water seems worthy of trial in combating scale insects. Such a wash should, of course, have approximately the same sulphur strength as the old lime-sulphur-salt wash and should require absolutely no heating to get the sulphur into solution. After a number of trials of different relative proportions of caustic soda, sulphur, and water it was found that if the formula as given below be used a mixture will be formed having in solution approximately the same amount of sulphur and the same sulphur compounds as the original lime-sulphur-salt wash, with the exception that these sulphur compounds exist entirely as the sodium salts instead of being present chiefly as calcium salts.

*Proposed Formula.**

Water	gallons..	50
Powdered sulphur	pounds..	19
Caustic soda	pounds..	10

The wash is mixed as follows: Make a paste of the sulphur with not more than 5½ gallons of boiling water; at once add all the caustic soda, which has previously been broken up into pieces the size of a hickory nut or smaller, and stir occasionally for one-half hour. At the end of this time add 44½ gallons of water, stir, and the wash is ready for use.

An analysis of the liquid portion of this wash for sulphur compounds shows the following composition:

	Grams per 100 cc.
Sulphur as thiosulphates	0.63
Sulphur as polysulphids and sulphids	2.85
Sulphur as sulphates and sulphites	.01
Total sulphur	3.49

* A wash somewhat similar to this has long been employed as a remedy for mites (sulphur 20 pounds, caustic soda, 98 per cent, 10 pounds, variously diluted), but not made according to the following directions nor with and understanding of its close chemical relationship to the lime-sulphur-salt wash.

It will be noted that this wash contains somewhat less sulphur than the original lime-sulphur-salt wash (formula—lime, 30 pounds; sulphur, 20 pounds; salt, 15 pounds; water, 60 gallons), but not enough to have any material influence. However, if others are of the opinion that it should be of exactly the same strength it can easily be made so by adding 39½ gallons of water instead of 44½ gallons of water, as given in the formula.

Again, it may be the opinion of many, and the opinion may prove to be correct, that it is best to add lime to this mixture, both on account of the fact that it serves as a guide in spraying and because it is less soluble in rain than caustic soda, and so will remain on the tree longer. If such is found to be the case the above formula could be used with the addition of about 17½ pounds of slaked lime. The directions for preparing this wash would then read:

Make a paste of the sulphur with about 5½ gallons of boiling water and add at once all the caustic soda, which has been previously broken up into pieces the size of a hickory nut or smaller, and stir occasionally for one-half hour, slake the lime with enough water to make a thick paste, and add the slaked lime to the mixture of sulphur, soda, and water. Add an amount of water equivalent to 50 gallons, minus the quantity already used in slaking the lime and making a paste of the sulphur.

Such a mixture as this is made in much the same way as one of the lime-sulphur-soda washes already described (p. 25), but different amounts of the ingredients are used and a slightly different procedure followed, which results in the solution of more sulphur and in the opinion of the writer produces a much better wash. It is believed, *on purely theoretical grounds and without having made field experiments,* that the first mixture proposed above, without lime, will give good results, especially in a dry climate. If this formula is deemed worthy of trial, reports as to its efficiency and the results obtained, as compared with those given by the lime-sulphur-salt wash, would be received with interest by the writer.

U. S. D. A., B. E. Bul. 58, Part I.   F. I. I., June 13, 1906.

Some Insects Injurious to Forests

THE LOCUST BORER.

(*Cyllene robiniæ* Forst.)*

BY A. D. HOPKINS.
In Charge of Forest Insect Investigations.

OBJECT OF PAPER.

The object of this paper is to give a summary of the more important published information, supplemented by recently determined new facts relating to the locust borer and methods of controlling it, which will be of service to the investigator in the determination of additional facts, and to the owners of plantations and forests in suggesting methods of preventing losses.

ECONOMIC IMPORTANCE OF THE INSECT.

The economic importance of the well known locust borer as affecting the growth of the black locust or yellow locust *(Robinia pseudacacia)* is fully realized by everyone who is interested in this valuable forest and shade tree, and the urgent need of additional information on the subject is indicated by the frequent inquiries of correspondents and by the recent articles in newspapers, journals, and special publications which have been called forth by the proposed extensive commercial planting of the locust by railroad and other companies and by individuals.

INVESTIGATIONS.

In connection with the general study of insects injurious to forest trees, the locust borer has received considerable attention by the writer since 1890.† In March, 1905, a plan of cooperation between the Bureau of Entomology and the Forest Service in the investigation of insect enemies of the black locust was proposed and adopted, by which the subject is receiving special attention from the viewpoint of both the forester and the entomologist, with the primary object of practical results.

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*Order Coleoptera, Family Cerambycidæ.

†From 1890 to 1892 for the West Virginia Experiment Station, and since 1902 for the U. S. Department of Agriculture.

CHARACTER OF THE INSECT AND ITS WORK.

The locust borer is a whitish, elongate, so-called "round-headed" grub or larva (fig. 1), which hatches from an egg (fig. 2) deposited by a black or brown and yellow striped long-horned winged beetle (fig. 3) found on the trees and on the flowers of golden-rod from August to October. The eggs are deposited in the crevices of the

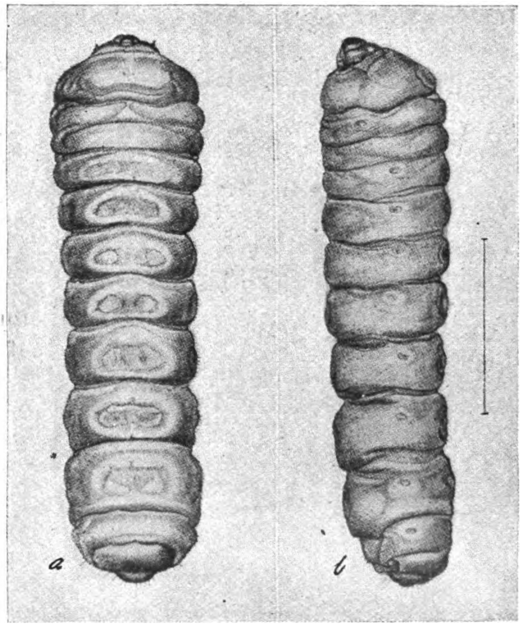
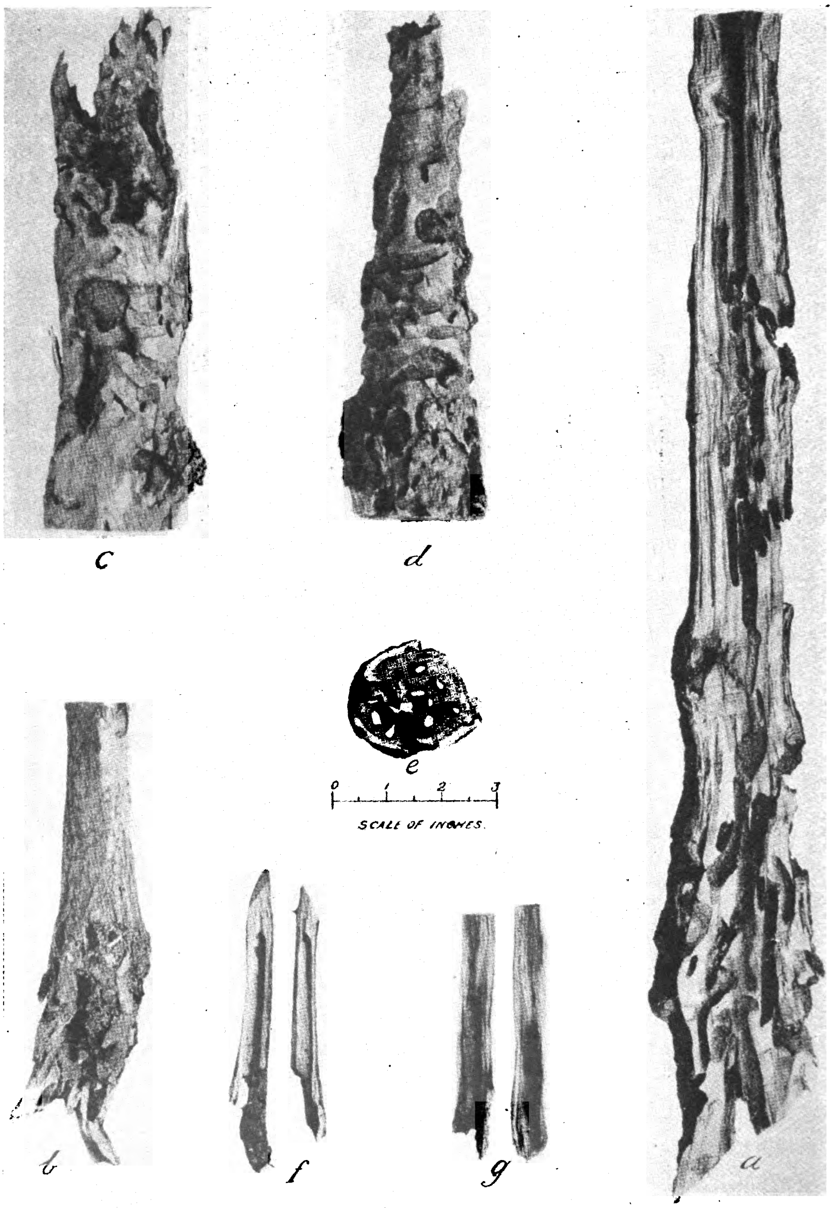


FIG. 1.—The locust borer (*Cyllene robiniæ*): *a*, larva, dorsal view; *b*, same, lateral view. Line at right represents natural length (original). The larva in profile should show minute prothoracic feet.

bark of living, growing trees from August to October, and the young borers (fig. 2, *b*, *c*) hatching therefrom mine into the outer portion of the living inner bark (fig. 5), where they pass the winter, and in the spring bore through the bark into the sapwood and heartwood. Here they transform in July and August to pupæ (fig. 4) and in August and September to adult beetles, which soon emerge from the trees and deposit eggs for the next annual generation of borers and beetles.

The injury to the trees (Pl. I) consists of wounds in the bark and sapwood which, if sufficiently severe or repeated year after year, result in either a stunted worthless growth or the death of young and old trees, while the numerous worm holes in the wood reduce its commercial value or render it worthless.



WORK OF THE LOCUST BORER.

a, Section of young tree 3 inches in diameter; *b*, section of young tree 2 inches in diameter, which was broken off near surface of ground; *c*, *d*, section of branch from badly damaged tree, showing healing wounds in surface of wood; *e*, transverse section of same; *f*, *g*, sections of branches one-half inch in diameter or less, showing in each the total length of burrow in which a larva developed and transformed to the adult beetle. (Original.)

The presence of the insect in injurious numbers is indicated (1) by the frequency of the adults on the golden-rod flowers and on the trees, from August to October; (2) by the slight flow of sap and by the brownish borings where the young larvæ are at work in the bark, during April and May; (3) by the whitish sawdust borings lodged in the rough bark, in the forks of the tree, and on the ground around the base of the trunk, during May, June and July; (4) by the breaking down of the branches and young trees, and by the sickly appearance of the young twigs and leaves in July and August.

This insect appears to be present and more or less injurious in all of that part of the United States which is east of the Great Plains and north of the Gulf States. Published information and reports of forest officials and others indicate that in Oklahoma and Indian Territory and west of the Great Plains the locust is now quite free from injury by the borer; but that these regions will remain exempt is by no means certain.

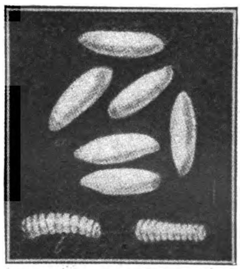


FIG. 2.—The locust borer (*Cyllene robiniæ*): *a*, eggs; *b*, *c*, larvæ from hibernation cells. Much enlarged (original).

EXTENT OF DAMAGE OR LOSS.

So extensive is the damage to natural growth, artificial plantations, and shade trees that in some sections within the natural range of the tree in the Eastern States, but particularly in the Middle West, where both the tree and the insect have been introduced, it is considered unprofitable to grow the tree for shade or timber, and in such sections the natural sprout growth is often considered a pest rather than otherwise.

The loss resulting from defective timber, stunted growth, and the death of trees is represented by the difference in value between the damaged growth or product and the same if uninjured and healthy. This, if expressed in dollars, would represent a large sum.

POSSIBILITIES OF PREVENTING LOSSES.

There are sections, especially in the natural home of the tree, where, as has been frequently observed by the writer and others, the damage is not sufficiently severe to seriously affect the vitality of the trees or the commercial value of the product; and our present knowledge of the insect and of methods of preventing losses from its ravages indicates that in properly selected localities, and under proper forestry methods of management, the tree, so far as this insect is concerned, can be grown successfully on an extensive scale, and can be made to yield most satisfactory returns.

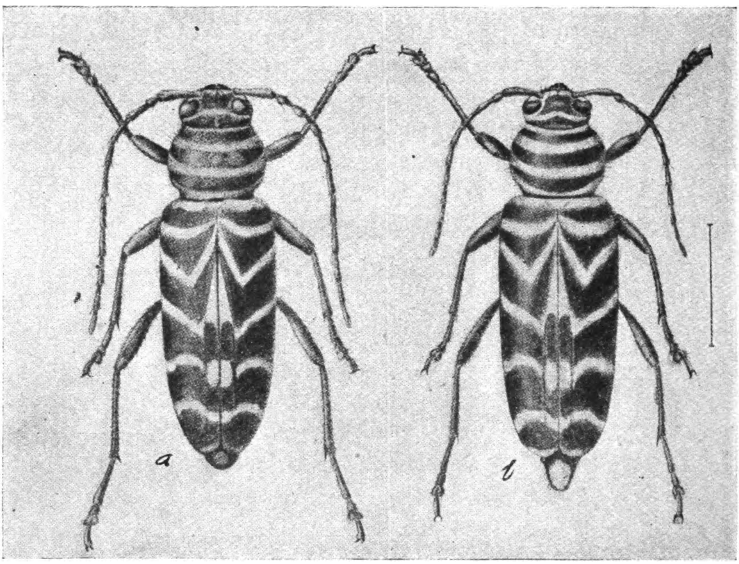


FIG. 3.—The locust borer (*Cyllene robiniæ*): *a*, male beetle; *b*, female beetle. Much enlarged (original).

HISTORICAL REFERENCES.

The first reference to this insect, according to Fitch, is a figure and description by Pitiver in his Gozophylacium, published in London in 1702. Drury figured it in 1770, and the following year, 1771, Forster gave it the specific name of *robiniæ*, under which it is at present recognized. It has been referred to many different genera, but is now recognized as belonging to the genus Cyllene. Both Drury and Forster received it from the "Province of New York," and referred to it as inhabiting the locust tree *(Robinia pseudacacia)*. It is therefore evidently an American species.

Some of the principal writers who have contributed important

facts on the life history, habits, distribution, and remedies are: Dearborn, 1821; Harris, 1826-1841; Fitch, 1858-1863; Walsh, 1865-1867; Riley, 1867; Lintner, 1890; Schwartz, 1890; the writer, 1891-1898; Felt, 1901-1905; Cotton, 1905; White, 1906, and others. (See list of publications, p. 15.)

REVIEW OF PUBLISHED DATA.

Gen. H. A. S. Dearborn was the first to record the more important facts in the life history and habits of the insect. Indeed, so complete and accurate were his observations that comparatively little has been added by subsequent writers, who have extensively

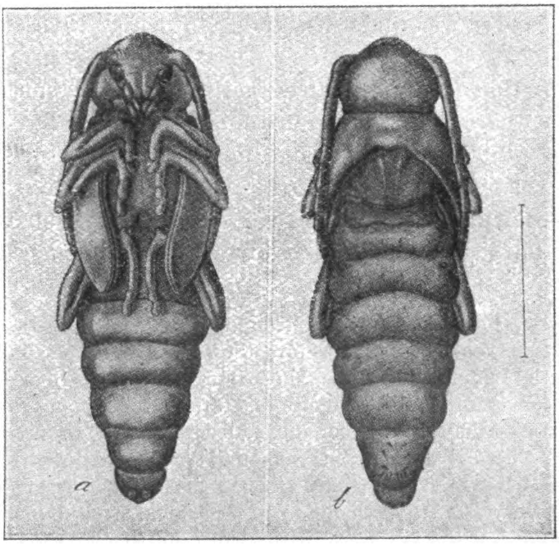


FIG. 4.—The locust borer (*Cyllene robiniæ*): *a*, pupa, ventral view; *b*, same, dorsal view. Much enlarged (original).

quoted and repeated them. He found the beetles on the trunks of trees from the 1st to the 25th of September, the females depositing their "snow white" eggs in the crevices of the bark, four to nine in each place. These eggs hatched before cold weather, and "the young larvæ just buried themselves in the tender inner bark," where they remained until about the 1st of April, when they commenced boring, and soon passed into the solid wood. He stated that it could always be ascertained when and where the borers were at work by the oozing of sap from the wounds made by them. By the 20th of July the larvæ attained their full size, by the 28th some of them changed to pupæ, and the perfect insects were on the

trees September 3. These observations were made on his grounds near Roxbury, Mass., during several years previous to 1821, when they were reported in a letter to John Lowell, and published, together with an account of his unsuccessful experiments with whitewash, mortar, and plaster, in the Massachusetts Agricultural Journal, Volume VI, 1821, pages 270-275.

Col. T. Pickering, in a letter to Mr. Lowell the same year and published in the same volume, stated that there were trees in New Hampshire uninjured by the borer, as well as in some of the Southern States; that he had observed the stems of young trees in Washington, D. C., infested, while in Georgetown (D. C.) he saw large, thrifty trees uninjured; and he concluded that natural growth in groves was much less liable to injury than transplanted growth.

Fitch, writing in 1858, stated that numbers of specimens were sent to him year after year from Indian Territory.

Schwarz (1890) observed that in and around the District of Columbia the insect lives in large colonies, affecting all trees of small groves, while long hillsides full of locust are not infested.

R. S. Kellogg, in his discussion of forest plating in western Kansas, says:*

> By locating plantation on good ground and giving it first-class care, the trees will reach fence-post size before the borers do much damage. They should then be cut and utilized. The rapid sprout growth will soon make a new crop. A stump sprout sometimes attains a height of 10 feet the first season. Handled in this manner, black locust can be profitably raised in many places where it is altogether unsuited for a permanent tree.
>
> At present borers are a menace to black locust trees throughout western Kansas and Nebraska, though there are occasional local areas that are not affected. They have so far done little damage in southwestern Kansas, but they are moving both southward and westward. They are abundant at Pratt, Kinsley, Dodge, and Scott, and are appearing at Medicine Lodge, Coldwater, Meade, and Garden City. Yet of the numberless trees that have been killed or seriously injured nearly all reached a size that could well be used for posts or stakes before succumbing. This shows that black locust may be successfully grown in commercial plantations if cut as soon as large enough for posts. * * *
>
> Just south of the Kansas line, in Woods County, Okla., black locust grows remarkably well, and has not yet been molested by borers.

Cotton (1905) observed that in Ohio injury was greater in single trees and plantations of considerable size than in natural forests.

Dearborn found that whitewashing the trees in April and filling the holes with mortar in July was not entirely successful as a reme-

*Bul. 52, Bur. Forestry, U. S. Dept. Agric., 1904.

dial measure, but he suggested cutting out and burning infested trees in April and protecting the young, thrifty trees. Harris suggested the collection of the beetles by children, and Fitch, the planting of golden-rod to attract the beetles, so that these could be collected and destroyed. Lintner suggested the application of soap solution and carbolic acid to prevent the beetles from depositing eggs, and the cutting out of young larvæ when their presence is indicated by sap and borings. Riley suggested destroying the young borers as soon as hatched. The writer recommended severe pruning in March, and clean culture was recommended by Felt.

The insect has been recorded from Canada southward to Pontchartrain, La., Texas, and Indian Territory, and westward into Nebraska. Some of the records of destructive ravages are the following: Peck (1818), Harris (1826), in New England; Fitch (1858), in New York; Rogers, Reed, and Bethune (1855 to 1867), in Canada; Walsh (1866), in Illinois and Kansas; Laurent (1893), around Philadelphia; the writer (1891 to 1898), in West Virginia; Smith (1898), in New Jersey; Cotton (1905), in Ohio; White (1906), in the Mississippi Valley, about twenty years after extensive planting was begun by settlers.

REVISION OF PUBLISHED DATA.

Some of the published records relating to the insect which have been frequently quoted or repeated require, according to the writer's observations, some amendments and corrections.

It would appear that normally but a single egg is deposited in a place, rather than clusters of four to nine. The female does not pierce the bark or place her eggs in the cambium layer. The larvæ do not enter the sapwood before winter, but, as observed by Dearborn and verified by the writer, remain in the outer portion of the inner bark. Records of the insect infesting honey locust are probably due to the fact that the black locust is sometimes referred to under this name, which is the correct one for an entirely different tree. It appears now that its attack is confined entirely to Robinia. It is not necessary that a tree or branch should be some inches in diameter before it is damaged, for the writer has found full-grown larvæ in sprouts and branches less than one-half inch in diameter.

In the writer's opinion, all attempts to cultivate locust in the eastern United States *should not be abandoned* on account of the borer, although this has been recommended by some recent writers. It has been stated that the locust would probably not be injured by the borer in the southern limit of its range and in the country

west of the Great Plains. While this may be true, precaution should be taken to prevent its introduction into such localities, since it is not improbable that if the insect be introduced and become established it may prove even more destructive there than in its natural home, as was demonstrated in the Mississippi Valley.

Nearly all methods heretofore recommended are subject to practical application to shade trees and small plantations only; therefore there is special need for suggestions of practical methods of combating the insect and preventing losses in large commercial plantations and in natural forest growth, and it is hoped that this paper will contribute something of value along this line.

OBSERVATIONS BY THE WRITER, 1890-1905.

Adults were collected on golden-rod flowers at Piedmont, Md., and Mineral County, W. Va., on August 25, 1890, and on golden-rod and locust leaves at Morgantown, W. Va., September 16 and 17, 1891. Young larvæ were found mining in living bark of trees at Kanawha Station, W. Va., May 1, 1891, and on May 20 the same larvæ had entered the wood, but a great many had died.

It was frequently noted that the locust in the forests of Chestnut Ridge in Monongalia and Pendleton counties, Laurel Hill in Preston County, and especially on Rich Mountain in Randolph County, W. Va., showed but slight damage by the borers. Similar observations were made in many other sections of the State, while in nearby and widely separated sections the damage was found to have been severe and continuous during the life of some of the older trees. In 1898 it was observed that badly damaged shade trees near Morgantown, W. Va., which had been severely pruned in March and April, had recovered, and the crowns were renewed by dense, vigorous, healthy growth, which suggested this method of treating badly damaged shade trees.

On October 9, 1904, it was found that the locust in the vicinity of Chevy Chase, Md., was but slightly damaged by the borer, although beetles were found in numbers on golden-rod and feeding on sap from wounds in bark of living sumac. This habit of feeding on sap is of special interest from the fact that it suggests the possibility of killing the beetles by means of a bait of some poisoned substance which would be attractive to them.

On May 23, 1905, it was found that the locust trees of all sizes in the open and in dense thickets along the old canal on Arlington Farm, Virginia, were thickly infested with the borers, which were

all in the wood and ranged in size from quite small to nearly full grown. The ground around some of the trees in the open and on the borders of the groves was found to be covered with the sawdust borings to the depth, in some cases, of an inch or more, and the larvæ could be distinctly heard at work in the wood. Some of the young trees had been literally honeycombed and were broken off at the ground, others had many branches broken and hanging by the bark or fallen from the tree, and some other trees had the leaves turning yellow and dying, while one isolated tree in a field had failed to put forth leaves on some of the branches. Some infested branches cut on this date and placed in a box in the laboratory were found on July 12 to contain fully matured adults, and on July 20 they began to emerge, thus showing that the larvæ will complete their development in the wood after it is cut from the tree and becomes perfectly dry. Indeed, this record shows that the dry condition contributes to the rapid development of the insect, for on the same day (July 20) on which the beetles were found in the box, the trees from which the branches had been cut were examined and found to contain nothing but larvæ. Some more branches were cut on this date and placed in a tin can, where they were kept moist. The first beetles emerged from these on August 24, or more than thirty days after adults had emerged from the dry branch. On August 30 many adults had emerged. September 20 ten living adults and many dead ones were taken from the can, and on October 2 several more dead ones were removed.

When the trees were examined on July 20, a larva was found mining in a two-year-old branch less than one-half inch in diameter, and the cocoon of a parasite of the borer was found in one of the mines, but the adult parasite was not reared. Many dead borers were found in their mines in the trunks and branches surrounded by a white powdery fungus.

The trees were again examined on September 14, when adults were found abundant on the foliage, branches, and stems, and also on flowers of golden-rod. Adults and pupæ were also found in considerable numbers in the dead wood of broken branches, as well as in the living wood, and dead larvæ were frequent. Larvæ of an elaterid (click beetle) were quite frequent in the wood, where they had evidently been feeding on the locust borer.

Examination during August, 1905, of the locust on a hill near Kanawha Station, W. Va., where this tree forms the principal growth over old abandoned fields and in the adjacent forests, showed that the damage by the borer was very slight in trees of all

sizes. On August 26 many adults and a very few pupæ, but no larvæ, were found in small trees in the valley, while the large trees in the same locality were but slightly damaged.

OBERVATIONS BY MEMBERS OF THE FOREST SERVICE.

The following notes by Mr. S. N. Spring, forest assistant in the Forest Service, were submitted October, 1905, as a contribution to the results of cooperative studies. Early in July the work of the borer was noticed in the central portion of Westmoreland County, Pa. The first adult insect was seen on August 29. Evidence of the work of this insect was found in the localities investigated, but, for the most part, it was not serious enough to prevent the planting of locust for fence posts. To the north and west of Greensburg, in Westmoreland County, and in Allegheny County many roadside trees were badly bored. The work of the borer is slight on Chestnut Ridge and Laurel Hill, where locust thrives. Posts and pit props cut in these mountains show slight injury only. In the few places where injury was found to be great, within the area studied, the trees were dying, and many branches were broken off where the trees had been extensively bored by this insect. Owing to the fact that places of serious injury were so few, it was impossible to carry out any observations that would be of value in a study of immunity. In general the locust on the two high ridges thrived better than those on the lower elevation of Westmoreland and Fayette counties, and less injury due to this insect was found among the trees on the ridges.

Mr. J. W. Fetherolf, of the Forest Service, informed the writer, on January 26, 1905, that a grove of black locust planted in Salt Lake City, Utah, prior to 1850, is still in a thrifty condition and apparently free from all insect injury. The same can be said about this species seen elsewhere in the Salt Lake Valley.

Mr. Wesley Bradfield, of the Forest Service, informed the writer that he found the adult beetles common on badly damaged trees, 5 to 8 years old, near Marshall, Mich., in August, 1905; also, that according to his observation the locust in the southern quarter of Michigan was seriously damaged, while in the northern three-quarters, especially toward Lake Michigan, it was not.

RECENT OBSERVATIONS BY THE WRITER.

On March 11, 1906, it was found at Arlington Farm, Virginia, that the young larvæ had passed the winter in minute cells which they had excavated in the outer layers of the living bark, and just

beneath the outer corky bark (fig. 5), as recorded by Dearborn. So common were these hibernating larvæ in the trees that in the bark of some of them there were fifteen or twenty within an area of a few square inches; but of the several hundred examined there was only one larva in a place, which would indicate that the eggs are not deposited in clusters, but that they are scattered about in the

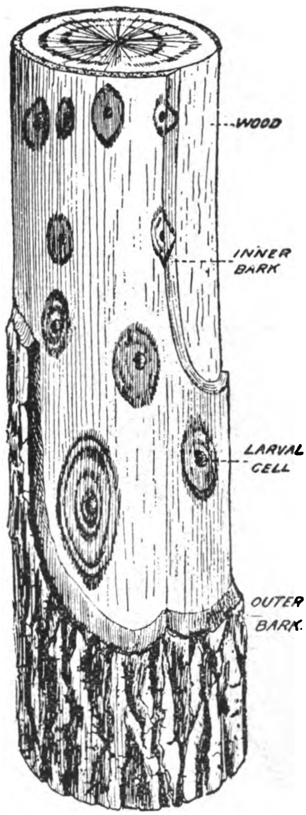


FIG. 5.—The locust borer (*Cyllene robiniæ*): Hibernation or larval cells in outer portion of living inner bark. About natural size (original).

crevices, so that each larva occupies a separate hibernating cell. The slight wound thus produced in the outer layer of the living bark results in a small dead area surrounding the cell. This dead and brown condition was found, on the date mentioned, to have penetrated the thick inner bark to the wood. This condition evidently facilitates the operation of the young larva in boring

through the inner bark to the wood, which a healthy condition of the immediately surrounding bark might prevent. It is not improbable that this small area of dead bark may be caused by a plant disease, which finds its way to the living plant tissue through the slight wound made by the larvæ and which, if this be so, may contribute greatly to the death of badly infested trees.

The young larvæ were found in nearly every case in the part of

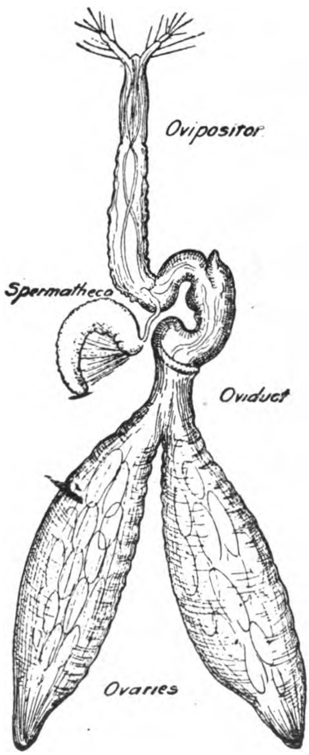


FIG. 6.—The locust borer (*Cyllene robiniæ*) Reproductive organs of female beetle. Highly magnified (original).

the bark which had not been injured previously, thus indicating that the female deposits her eggs where the bark is perfectly healthy and not in or around the old scars. Indeed, the habit of the larvæ appears to render this quite necessary for their more or less isolated work. It was particularly noted that the remaining unaffected bark of the trees which had suffered most from previous generations of the insect was thickly infested with hibernating

larvæ, while that of near-by large trees which had escaped previous injury contained very few, thus indicating that from some cause there are individual trees which are more or less immune. This fact, which has been so often observed, suggests the importance of experiments in the propagation of immune stock by means of seed or root cuttings from immune trees growing among badly infested ones.

The hibernating habits of the larvæ also suggest a simple method of destroying them, namely, the cutting and barking of the trees during the period between the first of November and the first of May. The simple removal of the bark, without burning, is sufficient to kill the larvæ.

It should be remembered that all the holes found in a tree and all other damage by the borer are not the work of one generation, but usually that of repeated annual attack during the life of the tree; also, that a burrow in the sapwood of a young tree remains the same burrow in the heartwood of the old tree, without change, except in the healing of the original entrance; therefore the number of borers and the amount of damage each year is not so great as it might appear, and, while each female is doubtless capable of depositing more than a hundred eggs,* it would appear from the writer's observations that only a small percentage of the larvæ hatching from them survive the bark-infesting stage or complete their development to the adult stage. This suggests that any method of management which will insure the destruction of a large number of larvæ and beetles each year will reduce the damage to a point where there will be practically no loss.

SUGGESTIONS FOR CONTROLLING THE INSECT AND PREVENTING LOSSES.

With our present knowledge of the life history and habits of the locust borer, it would appear that the following suggestions might be of practical value in the control of insects in large plantations and forests.

The fact that the young larvæ from eggs deposited during the summer remain in the outer bark during the winter and do not enter the wood until the following May suggests that if locust for all purposes were cut between November and May, the bark removed from that portion which is of value, and the remainder burned, it would destroy vast numbers of the insects and contribute greatly toward the protection of the remaining growth.

* An examination of the ovaries (fig. 6) of beetles collected in August shows that they may contain as many as fifty mature eggs at one time, in addition to a large number of immature ones.

The fact that badly infested trees may be detected during May, June, and July by the ejected sap and borings, suggests this simple method of locating such trees, which should be cut close to the ground and burned, before the first of August, to destroy the borers before they transform to the adult beetles and emerge. If preferable, the same end may be accomplished by burning the tops and worthless parts and by submerging the valuable parts in ponds or streams until the borers are killed.

DAMAGE TO CUT WOOD AND DANGER OF INTRODUCTION INTO NEW LOCALITIES.

As we have shown that after the borers have once entered the wood they may complete their development in the cut and dry branches, they will evidently do so in posts or other material manufactured from trees cut between the first of May and the middle of September; therefore, it is plain that locust should not be cut during this period for any purpose except to destroy the borers, or, if it should be necessary to cut it, the tops should be burned and the logs submerged in ponds or streams for a few days before they are shipped or manufactured. This is very important both to prevent damage to the manufactured material and the introduction of the insect into the far West and other sections of the country which are at present free from it.

PROPER LOCATIONS FOR EXTENSIVE PLANTATIONS.

The fact that there are many sections and localities of greater or less extent within the natural home of the locust and its insect enemies where, from some unknown cause, the tree grows to large size and old age without perceptible injury from borers and other insects, suggests the importance of selecting such localities for any proposed extensive operations in the line of artificial plantation, or utilization of natural growth. It will be found, however, that no area of considerable extent, even in such localities, is entirely free from this and other destructive insect enemies, and that certain precautions and well-planned methods of management with reference to their control will be necessary.

PRELIMINARY REQUISITES.

In the first place it is necessary, in order to provide against future losses from the borer, that a thorough survey be made in May and June, not only of the area to be utilized but of the entire neighborhood for a radius of a mile or more from its borders, for the purpose of locating and destroying scattering trees and groves

which are more or less seriously infested or damaged by the borer. It would seem that the control of such large areas, by purchase or under a plan of cooperation between the owners of the land or trees, is one of the most important requisites for success in preventing future losses from the ravages of this and other insects in small as well as large plantations. In fact, it is the writer's opinion that, with this precaution properly and continuously carried out, locust may be successfully protected from the borer in any locality.

SUBSEQUENT MANAGEMENT.

In the subsequent management of plantations and of natural forest and sprout growth it is important each year to locate and destroy the worst infested trees for the purpose of killing the borers in the wood, and to conduct the thinning and commercial cutting operations during the period between November of one year and May of the next in order to destroy the eggs and young before they enter the wood.

Worthless, scrubby, borer-infested trees should be killed outright by stripping the bark from 4 or 5 feet of the lower stem during August to prevent sprouts and seed production from them and at the same time to destroy the eggs and young borers. Trees deadened in this manner, as was demonstrated near Morgantown, W. Va., some year ago, may be so completely killed that not a single root sprout will appear. Therefore this method is of special value in preventing sprout reproduction from inferior individual trees.

COLLECTING THE BEETLES FROM GOLDEN-ROD FLOWERS.

Collecting the beetles from golden-rod flowers, by means of insect sweep nets, before they deposit their eggs, would be advisable, even for the protection of large plantations, and, as has been suggested, the planting of patches of the plant, or the cutting of all but certain strips and patches of natural growth for this purpose, would serve to concentrate the beetles where they could be caught in the nets and destroyed by emptying them into a pail containing water covered with a film of kerosene.

POISONED BAIT.

Experiments should also be made with poisoned baits, as suggested on pages 7-8.

SUGGESTIONS FOR PROPAGATING BORER-RESISTANT TREES.

FROM SEED (SEXUAL METHOD).

The fact that some trees are, to a greater or less extent, immune from attack or injury by the borer, while adjacent ones in the same grove are attacked year after year and seriously damaged, suggested the idea of breeding races and varieties of the species which would be permanently immune. This suggestion was included in the plan for cooperative investigation mentioned on pages 1-2. It was then thought that if the seed for general planting were collected from immune trees found growing among badly damaged ones, a much larger percentage of the product would resist attack and, by continuing this method of selection and breeding, immune varieties could in time be established. There are, however, some serious difficulties to be overcome by this sexual method, especially that of cross-fertilization and variation and the very long time required to get definite verified results.

FROM ROOT CUTTINGS (ASEXUAL METHOD).

It has since occurred to the writer that insect-resistant varieties might be secured by a much shorter method, namely, that of propagating from root cuttings and possibly from twig cuttings. By this simple method of asexual propagation a large number of offspring, in every respect like the parent stock, may be secured at once for the starting of experiments to determine whether or not the asexual product of trees which have not been injured by the borer will produce plantations equally as immune. The writer's experience in the establishment of improved varieties of timothy by this method leads him to believe that insect-resistant varieties of locust can be established. If so, the principal difficulties in the problem of preventing losses from the ravages of the borer will be solved.

It should be mentioned in this connection, however, that it is possible that the borer, if deprived of the trees which are most attractive to it, may gradually adapt itself to the more resistant ones and become more or less injurious to these, and that other insect enemies may be troublesome. There will be so many advantages however, in propagating from healthy, vigorous stock that, in the writer's opinion, the matter should receive immediate attention, and selection and propagating experiments should be started at once. The success of the effort will depend largely on the proper selection of immune trees from the worst infested groves or sections rather than from those growing in partially immune localities.

Domestic animals and cultivated plants have been improved by selection and breeding to meet almost every need and requirement of man, and it is well known that some races and varieties are much less susceptible to injury by disease and enemies than are others. It is reasonably certain, therefore, that the locust will not be an exception, but that it will yield to the breeders' manipulations and may be made to produce insect-resistant varieties and forms specially fitted to supply the different needs of commercial planting, shade, and ornament.

In the meantime, much of immediate practical value and importance may be accomplished by following the suggestions herein contained for the direct control of the insect in extensive plantations and in natural forest growth.

Some Insects Injurious to Forests

ADDITIONAL DATA ON THE LOCUST BORER.

(*Cyllene robiniæ* Forst.)*

BY A. D. HOPKINS.
In Charge of Forest Insect Investigations.

This part of Bulletin 58 contains a partial revision of Part I, with additional information based on the results of subsequent investigations by the writer and one of his assistants, Mr. W. F. Fiske.

SEASONAL HISTORY.

The data under this head refer to the District of Columbia and vicinity, latitude 39°, altitude 10 to 90 feet above tide.

HIBERNATION.

Hibernation begins soon after the larvæ hatch from eggs deposited at various times from August to October, and the period is passed as minute larvæ, scarcely longer than the eggs from which they hatch, in small individual hibernating cells excavated by them just beneath the corky bark and in the outer layers of the living bark on the main trunk of the larger to small trees or small saplings, and larger to small branches.

ACTIVITY OF THE OVERWINTERED LARVAE.

Activity of the overwintered larvæ begins in April, or with the beginning of the movement of the sap in the bark and just before the leaf buds open. In 1906 activity began April 11; on April 13 the more advanced individuals had entered to the wood, on the 16th were grooving the surface, and on the 25th some of them had entered the wood. By May 11 nearly all of them had entered the sapwood and some of them had extended their burrows into the heartwood and were rapidly increasing in size and very active, so that by May 20 some of them were more than half grown. They continued actively feeding and growing until after the middle of

*Order Coleoptera, Family Cerambycidæ.

July, when they began to transform to pupæ and continued transforming during August until all had transformed, probably by the 1st of September. The pupæ begin transforming to adults about the first of August and continue transforming probably into September, although the principal transformation is in August.

ACTIVITY OF THE ADULTS.

The adults begin to emerge as early as the 7th of August, and continue emerging until the last of September, the greater number coming out during the last part of August and the first half of September. Evidently all beetles are out by the first week in October.

The females begin to deposit eggs within a few hours after they emerge. The principal period of oviposition appears to be between the middle of August and middle of September, but oviposition continues until in October. The eggs hatch within eight or ten days after they are deposited, and the young larvæ excavate their hibernating cells and remain dormant until the following spring.

VARIATION IN SEASONAL HISTORY BETWEEN DIFFERENT LATITUDES AND ALTITUDES.

Phenological investigations of plants and insects by the writer* during the past ten years indicate that the average difference in the dates of occurrence of the different stages of *Cyllene robiniæ* at different latitudes and altitudes in the eastern United States will not be far from four days later for each degree north of latitude 39° and for each 400 feet of altitude above Washington at the same latitude, or four days earlier for each degree south of latitude 39° at the same altitude.

Thus, at latitude 43° in central New York, or central Michigan, with altitude the same as at Washington, the dates would be about sixteen days later, and at altitudes of 1,000 feet at latitude 43° they would be about twenty-six days later; at the same altitude as that of Washington at latitude 35° in southern North Carolina and Tennessee they would be about sixteen days earlier or at 1,600 feet elevation about the same. Thus we would have about thirty-two days' difference between localities at the same altitude in central New York and southern North Carolina. We would also have thirty-two days' difference between Washington and localities at latitude 39° and altitudes of 3,200 feet in the mountains of Virginia and West Virginia.

*Bull. 50, W. Va. Agric. Exp. Sta., 1898, pp. 17, 18, and Bul. 67, 1900, pp. 241–248, with map.

HABITS OF LARVÆ AND ADULTS.

When a larva begins activity in the spring it molts and proceeds to excavate an independent food and entrance burrow through the dead area of bark surrounding the hibernating cell or through the living bark immediately surrounding the dead area, until it reaches the cambium. It then excavates an irregular groove or cavity in the outer sapwood, returning frequently to the outer cell or opening to push out the borings and apparently to get relief from the exuding sap. A large per cent. of the larvæ die before any further progress is made, but survivors grow rapidly and soon succeed in overcoming the many obstacles, including natural enemies, resistance of the tree, etc., and enter the sapwood. From this stage on until the larvæ have attained their full growth they are very active and destructive. Their food consists principally of the nutritious substances of the bark and wood, and probably of the liquids flowing into the burrow, but they do not hesitate to kill and feed upon each other when two or more come in contact within the same burrow. The fact that the entire development often takes place in a burrow scarcely more than twice the length of a matured larva indicates that food must be obtained from some source other than the wood and bark. Throughout its active life the larva frequently returns to the inner and outer bark to enlarge the burrow, and push out its borings, so that the burrow when completed is of a diameter throughout sufficient to allow the passage back and forth of the full-grown larva. When full grown the larva enlarges the inner end of the burrow, plugs the outer portion with boring chips, and in due time transforms in succession to the pupa and adult. When the adult is fully matured it escapes through the exit prepared by the larva. Immediately after a female emerges she is joined by one or more males, and within a few hours, or within twenty-four hours, she proceeds to deposit eggs. She runs about over the bark investigating the crevices, by means of her ovipositor, to locate those most suitable for an egg. Sometimes as many as twenty places are critically examined before one is selected, and it appears that but one egg is deposited in a place by the same female, but other females may find the same place and each deposit an egg, so that sometimes several eggs are found in one crevice. As a rule, however, there is but one. The faculty of the female in locating the most suitable place for an egg by means of the sensitive palpi on the tip of the ovipositor is remarkable.

The beetles feed principally on pollen from the flowers of golden-

rod, but are very fond of any sweet liquid, such as sugar sirup placed on the trunks of the trees. They are found during the day on the trunks, branches and foliage of the locust, and during their principal period of activity, from toward the last of August to the middle of September, they are especially common on the golden-rod flowers. Mr. Fiske determined that they were also actively copulating and depositing eggs as late as 10 o'clock at night.

The attack of this insect is apparently confined to the black or yellow locust *(Robinia pseudacacia)*.

ECONOMIC FEATURES.

DESTRUCTIVE CHARACTER OF THE WORK.

The destructive character of the work of the locust borer is a matter of great economic importance. This insect attacks the otherwise perfectly healthy trees, and in addition to causing the detrimental wormhole defects in the wood it often kills the trees or renders an otherwise valuable product worthless except for fuel. It is much more destructive in some localities and sections than in others, and also much more destructive to some trees in the same grove than it is to others. It is more destructive also to young saplings and the branches of medium-sized trees than to the larger trees.

The death of a tree is caused principally by injuries to the inner bark and cambium, resulting from repeated attacks. Injuries to the wood alone do not result in the death of trees except when all of the wood is practically destroyed or sufficiently injured to cause the tree to fall or be broken down by the wind.

The commercial value of the wood product is diminished or destroyed by the wormhole defects, but for certain purposes, as, for instance, fence posts, a limited number of such defects are not detrimental, except so far as they may contribute to decay.

EVIDENCES OF ATTACK.

The first evidence of attack is fine brownish boring dust and wet spots on the bark, first observed in April, when the overwintered larvæ begin to enter the inner bark. As soon as the larvæ begin to groove the surface of the wood and enter the sapwood, their presence, in addition to the wet spots, is indicated by yellowish boring dust mixed with liquids and the gum-like exudations. After all of the larvæ have entered the wood their presence is plainly shown by the quantities of yellowish boring dust lodged in the loose bark on

the trunk, in the forks of the tree or branches, and around the base. At this stage, usually about the middle of May, the badly infested trees which will die are plainly indicated by the failure of the leaf buds to open, or by the dwarfed or faded and sickly appearance of the foliage, and toward the last of the month and until the larvæ have completed their work in July, by the breaking down of the branches and small trees.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR DESTRUCTIVE WORK.

Favorable conditions for the destructive work of the borer appear to be found in the presence of isolated trees and groves in the open in localities where golden-rod is present or abundant; also, where less resistant varieties of the tree prevail.

Unfavorable conditions are found in forest growth or large areas of pure stands, or mixed stands where the locust predominates; also, in plantations and groves where resistant varieties prevail, and where there is no golden-rod or other favorite food for the beetles. It is also found that coarse, thick bark is less favorable than the thinner bark on old and young trees and saplings.

NATURAL ENEMIES.

INSECTS.

Several predaceous insect enemies of the larvæ have been observed, but so far no true parasites have been discovered. A large elaterid larva (*Hemirhipus fascicularis* Fab.) appears to be the principal enemy of the borer after the latter has entered the wood. It resembles the borer somewhat, but is easily distinguished by the more flattened and shiny body, long prothoracic legs and two curved spines on the last abdominal segment. This predaceous larva is frequently found in the empty mines of the Cyllene larvæ, therefore it is evidently an enemy of considerable importance.

A slender, cylindrical, whitish, footless dipterous larva of an undetermined species is sometimes found in the mines in the wood, and, according to an observation made by Mr. Pergande, it may attack and kill the borers.

Whitish, flattened larvæ of the nitidulid genus Ips, with prominent branched hooks on the last abdominal segment, are common in the sap at the entrance of the mines and in the burrows made by the young borers in the inner bark and outer wood. They are supposed to be sap feeders, but the writer found they would attack and devour young Cyllene larvæ when confined together in a bottle. Therefore it is possible that they kill a great many of the young

borers before these enter the wood, which may account, in part, for the disappearance of such a large number of the young borers while in the bark-boring stage.

It was also demonstrated that if several young Cyllene larvæ of various sizes were placed together in a small vial, the larger ones would kill and eat the smaller ones. It is probable, therefore, that when several larvæ hatch from a cluster of eggs and but one survives—which is usually the case—the larger or stronger one has killed the weaker ones.

DISEASE AND SAP FLOW.

Dead larvæ are frequently found in the mines, covered with white flour-like spores, and sometimes these spores are so common that a perceptible cloud rises from the wood when it is split open. Experiments in placing some of the spores with healthy uninjured larvæ in bottles, as well as with those in the normal position in the wood, resulted in the death of the larvæ and the development of apparently the same disease, while the duplicate larvæ kept under the same conditions, but without contact with the spores, remained normal and healthy. Therefore this is a fungus which will kill the borers and one which is evidently of considerable importance.

The profuse flow of sap together with a gummy substance in the wounds made in the living bark and cambium is evidently detrimental to the normal progress of the young larvæ and apparently many of the latter are thus destroyed.

METHODS OF CONTROL.

It should be remembered that all the holes found in a tree and all other damage by the borer are not the work of one generation, but usually that of repeated annual attack during the life of the tree; also, that a burrow in the sapwood of a young tree remains the same burrow in the heartwood of the old tree, without change, as long as the tree exists, except in the healing of the original entrance. The number of borers and the annual amount of damage is not so great, therefore, as might appear, and, while each female is capable of depositing a hundred eggs, only a small percentage of the larvæ hatching from them survive the bark-infesting stage or complete their development to adults. This suggests that any method of management which will insure the destruction of a large per cent of the surviving larvæ and beetles each year will reduce the damage to a point where there will be practically no loss.

With our knowledge of the life history and habits of the insect it

is now possible to make definite recommendations and suggestions for its control. Some of those of immediate practical importance are as follows:

TIME TO CUT LOCUST TO DESTROY THE YOUNG LARVAE.

The cutting of locust for all purposes, including thinning operations and for private or commercial use, should be done during the period between the 1st of October and the 1st of April, the bark removed from the crude product, such as posts, poles, and the like, and the tops and thinnings burned. The removal of the bark from all desirable portions of the trunks of the trees felled during this period is important and necessary in order to destroy the larvæ before they enter the wood. The work in all cases should be completed before the leaf buds begin to swell on the living trees in the spring.

DESTRUCTION OF INFESTED TREES AND WOOD.

When it is desirable to simply remove and destroy, by burning or otherwise, the badly infested and damaged trees to kill the broods of larvæ, the work should be done in May and June, when all such trees can be easily recognized by the boring dust, fading leaves, broken branches, etc., and must be completed before the beetles begin to emerge. Perhaps the best rule, applicable to all localities, latitudes, and elevations, is to complete the work by the time the flowers have all fallen from the trees, which will vary between different altitudes and latitudes from about the middle of May to the last of June. Another rule would be to complete the work before the earliest varieties of golden-rod begin to show evidences of flowering. This, however, would be the latest that the work should be done, because the beetles begin to emerge by the time the first golden-rod flowers appear.

SPRAYING THE TRUNKS AND BRANCHES TO KILL THE YOUNG LARVAE.

Experiments have demonstrated that the hibernating larvæ may be killed by spraying the trunks and branches with a strong solution of kerosene emulsion. Therefore, when it is practicable or more desirable to adopt this method for the protection of small plantations, groves, or shade trees, the spraying should be done in the fall or winter, not earlier than November 1, and not later than April 1—in other words, during the dormant period of the tree. The following paragraphs, relative to the preparation of kerosene emulsion, are taken from Farmers' Bulletin No. 127, by C. L. Marlatt:

Kerosene emulsion (soap formula)—

Kerosene	gallons..	2
Whale-oil soap (or 1 quart soft soap)	pound..	½
Water	gallon..	1

The soap, first finely divided, is dissolved in the water by boiling and immediately added, boiling hot, away from the fire, to the kerosene. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely, and should be diluted only as wanted for use.

For the treatment of large orchards or in municipal work requiring large quantities of the emulsion, it will be advisable to manufacture it with the aid of a steam or gasoline engine, as has been very successfully and economically done in several instances, all the work of heating, churning, etc., being accomplished by this means.

The use of whale-oil soap, especially if the emulsion is to be kept for any length of time, is strongly recommended, not only because the soap possesses considerable insecticide value itself, but because the emulsion made with it is more permanent, and does not lose its creamy consistency, and is always easily diluted, whereas with most of the other common soaps the mixtures becomes cheesy after a few days and needs reheating to mix with water. Soft soap answers very well, and 1 quart of it may be taken in lieu of the hard soaps.

In limestone regions, or where the water is very hard, some of the soap will combine with the lime or magnesia in the water and more or less of the oil will be freed, especially when the emulsion is diluted. Before use, such water should be broken with lye, or rain water employed. * * *

For use on locust trees dilute 1 gallon of emulsion with 2 gallons of soft water.

Pure kerosene and pure petroleum will effectually kill the insects, but may do some damage to the bark of the trees.

Experiments with carbolic emulsion indicate that this preparation is of no value to kill the young larvæ.

POISON BAIT.

Experiments showed that the beetles would feed readily on poisoned bait, such as sugar, sirup, or molasses with some arsenical mixed in, when this was smeared on the trees. Such baits are fatal to the beetles, but the danger of killing honeybees is so great that their use is not recommended in localities where honeybees are kept.

DAMAGE TO CUT WOOD AND DANGER OF INTRODUCING THE INSECT INTO NEW LOCALITIES.

We have determined that after the borers have once entered the wood they may complete their development in the cut and dry branches; they will evidently do so, therefore, in posts or other material manufactured from trees cut between the 1st of May and the middle of September; from this it is plain that locust should not be cut during this period for any purpose except to destroy the borers, or, if it should be necessary to cut it, the top should be burned and the logs submerged in ponds or streams for a few days before they are shipped or manufactured. This is very important, both to prevent damage to the manufactured material and the introduction of the insect into the far West and other sections of the country which are at present free from it.

SELECTION OF LOCATIONS FOR EXTENSIVE PLANTINGS.

The fact that there are many sections and localities of greater or less extent within the natural home of the locust and its insect enemies where, from some unknown cause, the tree grows to large size and old age without perceptible injury from borers and other insects, suggests the importance of selecting such localities for any proposed extensive operations in the line of artificial planting, or utilization of natural growth. It will be found, however, that no area of considerable extent, even in such localities, is entirely free from this and other destructive insect enemies, and that certain precautions and well-planned methods of management with reference to the control of the latter will be necessary.

MANAGEMENT OF PLANTATIONS TO PREVENT INJURY.

In the first place it is necessary, in order to provide against future losses from the borer, that a thorough survey be made in May and June, not only of the area to be utilized but of the entire neighborhood for a radius of a mile or more from its borders. for the purpose of locating and destroying scattering trees and groves which are more or less seriously infested or damaged by the borer. It would seem that the control of such large areas, by purchase or under a plan of cooperation between the owners of the land or trees, is one of the most important requisites for success in preventing future losses from the ravages of this and other insects in small as well as large plantations. In fact, it is the writer's opinion that, with this precaution properly and continuously carried out, locust may be successfully protected from the borer in any locality.

In the subsequent management of plantations and of natural forest and sprout growth it is important each year to locate and destroy the worst infested trees for the purpose of killing the borers in the wood, and to conduct the thinning and commercial cutting operations during the period between October of one year and April of the next, in order to destroy the young borers before they enter the wood.

Worthless, scrubby, borer-infested trees should be killed outright by stripping the bark from four or five feet of the lower stem during August to prevent sprouts and seed production from them, and at the same time to destroy the eggs and young borers. Trees deadened in this manner will usually be so completely killed that not a single root sprout will appear. Therefore this method is of special value in preventing sprout reproduction from inferior individual trees.

SELECTING AND BREEDING BORER-RESISTANT TREES.

The fact that some trees are more or less resistant to attack or injury by the borer, while adjacent ones in the same grove are attacked year after year and seriously damaged, suggests breeding races and varieties of the species which would be permanently resistant.

Breeding experiments have been begun in cooperation with the Bureau of Plant Industry and the Forest Service, but it will require several years to get definite results. In the meantime, however, it is important that seed and cuttings for commercial planting should be selected, as far as possible, from trees which show least damage from the borer and are otherwise vigorous and healthy. From a well-established principle in the heredity of plants and animals, this practice of propagating from the best examples must certainly yield better results than would follow a disregard of the character of the trees from which seed or root propagations are made.

For reference to literature, and other information not included in this paper, the reader is referred to Part I of this bulletin, pages 1 to 16.

UNITED STATES DEPARTMENT OF AGRICULTURE,
Forest Service—Circular 61, Issued February 5, 1907.
GIFFORD PINCHOT, FORESTER.

Forest Planting Leaflet

HOW TO TRANSPLANT FOREST TREES.

The tree planter should endeavor always to transplant his trees with the least exposure of the roots. The root-hairs, or feeding cells, on the roots of a plant will shrivel up and perish if exposed to the dry atmosphere for even a few minutes. The roots of conifers are particularly sensitive, so that these require more careful attention in transplanting than do broadleaf trees. Some of the broadleaf species may have their roots dried out and shriveled, yet with proper attention revive and live; but the conifers, once dried, rarely regain their vitality.

THE PROPER SEASON.

The best time to transplant young trees is just before growth begins in the spring, when the seedlings are likely to receive the least injury. In general, planting should be done as soon as possible after the frost is out of the ground, the exact period depending upon local climate and soil conditions. In parts of the country where the winter is the only season with an abundant rainfall, the transplanting should be done during the rainy season.

Fall transplanting in the prairie States is usually unsatisfactory, since the dry, freezing weather of winter often damages the young shoots. In the States east of the Mississippi fall planting is more successful, though small seedlings are often likely to be heaved out by the frost if not protected by mulching.

Conifers, with the exception of the deciduous species, such as European larch and tamarack, may be safely planted somewhat later in the season than broadleaf trees.

It is always well to choose a wet or cloudy day for transplanting, but if the work must be done in dry weather, the nursery beds or trenches should be thoroughly soaked a few days before removing the trees. By establishing a home nursery close to the planting site the disadvantages of shipment may be avoided, some expense may be saved, and the time of planting may be considerably extended. The last point is often of importance, because it may be inconven-

ient to drop other work in order to give a shipment of trees the immediate attention they require. Home-grown stock may be left in the nursery until a favorable opportunity for getting out the trees occurs.

TREATMENT BEFORE TRANSPLANTING.

As a rule, seedlings from one to three years old are the best for forest plantations, and those of most species require no preliminary preparation. Older trees, however, and certain conifers like Coulter pine, western yellow pine, longleaf pine, and such broadleaf trees as form long taproots, should have their roots pruned in the seedbeds. This may be done late in the summer by running a "tree digger" under each row of trees and allowing the plants to stand undisturbed for another season, or, with small seedlings, the roots may be pruned with a sharp flat spade or a special implement designed for the purpose.

European foresters move young trees with balls of earth adhering to their roots, such trees being called "ball plants." Where the eucalyptus is cultivated on a large scale the seedlings are frequently prepared for easy transplanting by being grown in "flats" or seed boxes made of some durable wood. The plants may then be removed with a small block of earth attached to the roots.

When the trees to be moved are large they are often prepared by digging them partly out in the fall, so that a large ball of earth may be frozen to their roots. The block of frozen soil, with the tree in it, is moved during the winter season to a hole which was dug before the ground became frozen.

PUDDLING.

When a seedling or transplant is taken from the ground, its roots should immediately be plunged into a vessel containing a mixture of earth and water about as thick as cream. This mixture is known as "puddle," and is one of the most important requisites for successful tree planting.

The puddle may be prepared in a pail, tub, or barrel, according to the size and number of the trees to be transplanted, and may be carried or drawn along the rows where the digging is in progress. If the trees are to be planted immediately, the vessel holding the puddle may be used as a receptacle to carry them from the nursery to the planting sites.

HEELING IN.

If seedlings are received from a distance, the trees should be unpacked at once and their roots should be dipped into a puddle. After this the trees should be "heeled in" according to the following method until the time for planting in the field:

Dig a trench deep enough to bury the roots and part of the stems. The trench should run east and west, with its south bank at a slope of about 30 degrees to the surface of the ground. A layer of trees should be placed in the trench on its sloping side, the tops toward the south. The roots and stems should be covered with fresh earth dug from the second trench, in which a second layer of trees is put and covered in the same way. The digging of the parallel trenches is repeated and layers of trees are put in until all have been heeled in. (See fig. 1.)

In the case of conifers care should be taken not to bury the foliage, and either to choose a shady place for the young trees or to construct a shade over them with brush or laths.

TRANSPLANTING IN NURSERIES.

With most species, especially with conifers, where seeds are planted in beds, it is necessary to transplant a portion of the young seedlings to nursery rows when they are one or two years old. This stimulates the growth of small roots, makes the plants much more vigorous than others of the same age not transplanted, and helps them to establish themselves better when permanently set out.

When the seedlings are dug from the seedbed they should be dipped in a puddle and immediately be set in the nursery rows, or,

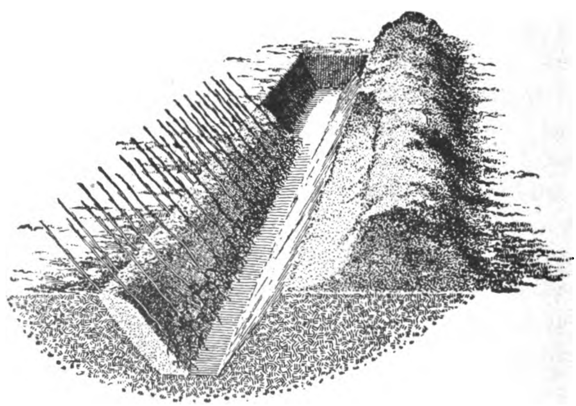


FIG. 1.—Heeling in young trees

if delay is necessary, they should be laid, roots together, in piles of a hundred or more, and the roots should be covered with wet blankets or with a few shovelfuls of fresh earth.

In ordinary nurseries which are to be cultivated by hand the rows for conifers should be 1 foot apart and those for broadleaf trees 2 feet apart. Coniferous seedlings should be set 4 inches apart in the row and broadleaf seedlings about 6 inches apart. All plants should be set from 1 to 2 inches deeper in the rows than they grew in the seedbed. If the seedbeds are not wanted for another planting, the seedlings to be transplanted may be taken out in such a way that thrifty plants will be left with the same intervals as in the nursery rows. They should then be cared for the same as transplants.

Some trees, like the oaks, the walnut, and the catalpa, form long, fleshy taproots during the first season, with few lateral roots. This form of root is sometimes very troublesome to transplant. Before setting such plants in the nursery rows from one-fourth to one third of the taproots should be cut off. A bundle of a hundred or more plants may be laid across a log and their taproots cut off with a sharp axe. Care must be taken not to bruise the part of the root that is left. Seedlings with a bunch of short, fibrous roots need no cutting.

Following the transplanting of seedlings the nursery rows should be kept clear of weeds and the soil stirred frequently with hoe or cultivator. It is especially necessary that the nursery be gone over after a rain as soon as the surface soil is dried out sufficiently to work well. This will prevent the deeper moisture from drying out about the roots of the trees. In case no rain falls within two weeks after the plants have been set in the nursery, water should be applied to the rows. In dry regions frequent shallow cultivation to maintain a dust mulch should be given.

TRANSPLANTING FROM NURSERY TO FIELD.

On the plains and prairies, the land, provided it has not been in a cultivated crop the preceding season, should be plowed deeply in the fall previous to planting and left rough over winter. In the spring it should be worked to a mellow condition and marked for planting in check rows or listed if the trees are to be planted in furrows. Virgin prairie soil should be allowed to lie one year after fall plowing in order that the dense sod may become thoroughly rotted. Subsequent treatment of such land is the same as that already described. In the east, and on non-arable ground, prelimi-

nary preparation of the soil by plowing and harrowing may be dispensed with.

In transplanting seedlings from the nursery to the permanent place in the field, the same care should be taken to prevent the exposure of their roots to the air as when transplanting them to the nursery rows. The best plan is to carry the trees, roots downward, in a pail containing several inches of water.

On land prepared by plowing and harrowing the seedlings may be set in furrows plowed for this purpose or in the rows previously marked with a lister for guidance of the planters. In the latter case a spade may be used for opening the hole. On unprepared sites the seedlings are set in holes dug with a grub hoe or mattock. The width and depth of the hole depends on the character and size of the plant's root system. In all tree planting it is of the greatest importance to press the earth firmly about the roots so that all air spaces are filled. The soil should not, however, be packed so hard as to be impervious to water nor should the earth be raised in a mound about the stem. In dry regions it is always desirable to leave a slight depression around the collar of the plant in order to collect any moisture that may fall.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 24, 1906.

BUR OAK (QUERCUS MACROCARPA).

FORM AND SIZE.

The bur oak is one of the largest trees found in central North America. It freqnently attains a height of from 80 to 90 feet and a diameter of from 3 to 4 feet. Under the most favorable conditions it has reached a height of 170 feet and a diameter of 7 feet. When grown free the crown is large and heavy; in the forest it is usually contracted and covers only the upper part of the tree.

The distinguishing feature of the bur oak is that from which it gets its name—the mossy fringe about the rim of its deep acorn cup. The leaf is large and deeply lobed and resembles that of the white oak. When the twigs are from three to four years old they begin to develop corky wings, which sometimes attain a width of an inch or more. These disappear as he branch grows older, and consequently are seen only on the younger growth.

RANGE.

The natural range of the bur oak is from Manitoba to Texas, and eastward to the Atlantic coast. It is commonest and most important in the lowland forests of the Mississippi basin, where it is found associated with white oak, basswood, white ash, cottonwood, black walnut, and several hickories. In the Dakotas and about the Great Lakes it sometimes occurs in pure stands, forming the characteristic "oak openings." East of the Allegheny Mountains it is comparatively rare and local, and near the northern and northwestern limits of its range it dwindles to a mere shrub. Bur oak may be planted on good soils almost anywhere east of the ninety-eighth meridian and in favorable situations somewhat farther west.

SILVICAL QUALITIES.

The bur oak is best suited to deep, rich, river-bottom soils. It will maintain itself in poorer upland localities, but it is recommended for planting only where the soil is fairly good, moist, and well-drained, and where protracted droughts are infrequent. It is rather intolerant of shade, and will not thrive beneath the crowns of taller trees.

The rate of growth, except under the best conditions, is somewhat slow, and is about like that of white oak. Neither grows so rapidly as red oak. The bur oak is subject to comparatively few pests or diseases.

ECONOMIC USES.

The bur oak is one of the most valuable hardwood trees in North America. The wood is heavy, hard, very strong, and durable. In the markets it is not, and need not be, distinguished from white oak, and it is used for the same purposes. The heartwood makes especially good fence posts and railroad ties, but the sapwood does not last long in the ground.

The tree is highly desirable for planting about the home, as well as for general forest planting where quick growth is not important.

METHODS OF PROPAGATION.

The bur oak reproduces freely both by acorns and by stump sprouts. The acorns, like those of all the white oaks, mature in one season, and germinate soon after falling, unless they are collected and cared for. They should therefore be planted, if possible, in the fall, either in seed beds or in their final place. Mice and squirrels

are fond of acorns, and sometimes destroy plantations made in the fall. Where this is to be feared, or where for any other reason it is necessary to hold them over until spring, the acorns may be stored between layers of moist sand.

To secure vigorous sprouts the trees should be felled between November and March, and the stumps should be cut low and left smooth and slanting on top. Sprouts then start close to the ground, where they can soon develop root systems of their own and become self-supporting. The slanting stump causes the rain water to run off, and thus helps to prevent rapid decay.

The bur oak has one well-developed taproot, and, in moderately rich and moist soils, many spreading secondary roots close to the surface. In dry soils the roots seek moisture at considerable depth.

PLANTING.

It is usually advisable to plant acorns in their permanent place in the field, for, like all oaks, the bur oak is not easy to transplant when once fairly established, because of its stout taproot.

Where the area to be seeded can not be plowed, the acorns should generally be planted in holes about 4 feet apart each way, although the proper distance will depend to some extent upon local conditions. Three or four acorns should be placed in each hole and covered with about 1½ inches of earth. If the planting is done on plow land, the soil may be prepared as for any field crop.

Bur oak can be grown in pure stands, but it is often desirable to mix one or two slower-growing species with it, in order to force the trees to grow tall and to clear the stems of their lower branches.

Bur oak should not be planted with trees which grow very rapidly, nor where the climate is so dry that the soil needs much cultivation to preserve its moisture. Care should be taken to keep the little trees from being smothered by grass and weeds, to keep out stock and fire, and to let the plantation acquire the character of a forest as soon as it can. Weeds and litter on the ground, and shrubs that stand below the crowns of the trees, are good and should not be interfered with.

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RED OAK (QUERCUS RUBRA).

FORM AND SIZE.

The red oak is one of the largest trees in the forests of the Northern States. The average height of mature trees is from 70 to 90 feet, and the diameter from 2 to 4 feet. Under the most favorable conditions a height of 150 feet and a diameter of 5 feet is attained. When grown free the tree has a broad and symmetrical crown and a short stem; in the forest it is tall and straight, with a small, narrow crown. On loose soil the base is often enlarged or buttressed.

RANGE.

The natural range of the red oak is from Nova Scotia to west of Lake Superior and south to eastern Kansas and northern Georgia. It is very common and well developed in the Northern and Central States, where it usually is associated with other oaks, basswood, elms, chestnut, and hickories. Toward the extreme limits of its range it becomes rare and of small size.

Red oak is recommended for planting anywhere within the limits of its natural range, on soils of medium quality, and on those which have become exhausted by cultivation.

SILVICAL QUALITIES.

Red oak is best suited to porous sandy or gravelly clay soils. In this requirement it is intermediate between the white oaks and several of the black oak group. It requires well-drained soil always, but does not do well where the air is very dry.

The tree is intolerant of shade, except when very young, and must always be allowed to keep its crown free.

Red oak surpasses all other oaks in the rapidity of its growth, and is therefore a good tree to plant where conditions are suitable.

Like the other oaks, this species is not subject to disease, nor to serious insect attacks, and is rarely overthrown by wind.

ECONOMIC USES.

The wood of red oak is heavy, hard, coarse-grained, strong, and moderately durable. It is inferior to white oak where great strength is required, and does not last so long in the ground, but it works easier, and is often preferred for interior finish and for cabinet work. Good red oak is often sold as white oak, and for most purposes the two need not be distinguished. Ordinarily it is distinctly better than other species of the red oak group.

METHODS OF PROPAGATION.

The red oak reproduces freely both by acorns and by stump sprouts. The acorns require two years to reach maturity. They are quite bitter and are not relished by squirrels, and hence can be planted in the field with less risk than white oak acorns.

To secure vigorous sprouts, the trees should be felled between November and March; the stumps should be cut low and left smooth and slanting on top. Sprouts then start close to the ground, where they can soon develop root systems of their own and become self-supporting. The slanting stump causes the rain water to run off, and thus helps to prevent rapid decay.

Red oak develops a taproof, which in loose soil grows strong and penetrates to a considerable depth, but in shallow soil may be replaced by strong secondary roots.

PLANTING.

It is usually advisable to plant acorns in their permanent place in the field, for, like all oaks, the red oak is not easy to transplant when once fairly established, because of its stout taproot.

Where the area to be seeded can not be plowed, the acorns should be planted in holes about 4 feet apart each way, although the proper distance will depend upon local conditions. Three or four acorns should be placed in each hole and covered with about 1½ inches of earth. If the planting is done on plow land, the soil may be prepared as for any field crop.

Red oak can be grown in pure stands, but it will often do well with other oaks, sugar maple, white elm, chestnut, white pine, and hickories. With chestnut and hickories red oak needs to be given a start of two or three years, so that it will not be overtopped; but other oaks, elm, sugar maple, and white pine may be planted at the same time. Fast-growing trees, like locust, should not be planted with red oak, unless they are certain to be cut back whenever their branches interfere with the latter.

Plantations of red oak need very little care, except where the rainfall is so deficient that the soil must be cultivated to conserve the moisture. All that is ordinarily necessary is to see that the little trees are not smothered by grass and weeds, that stock and fire are kept out, and that the plantation acquires the character of a forest as soon as it can. Weeds and litter on the ground and shrubs that stand below the crowns of the trees are good and should not be interfered with.

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SHAGBARK HICKORY (HICORIA OVATA).

FORM AND SIZE.

The shagbark hickory is a forest tree which commonly attains a height of 70 to 80 feet and a diameter of about 2 feet. Under favorable conditions, a height of 120 feet and a diameter of 4 feet is reached. When grown free the stem often branches near the base and the crown becomes full, though it always remains narrow; in the forest, the crown is short and small, while the stem frequently has a clear length of from 50 to 60 feet.

The characteristic feature of the shagbark hickory, from which it gets its name, first appears in the older trees in the long, loose plates or strips of bark which are produced on the trunks. On young trees the bark is very smooth and close.

RANGE.

The natural range of shagbark hickory is from southern Maine west through southern Michigan to eastern Kansas, Nebraska, and Texas, and south along the Appalachian Mountains to Florida, Alabama, and Mississippi. It reaches its best development on the western slopes of the Appalachians and in the regions drained by the tributaries of the Ohio River.

The shagbark hickory is generally found in mixture with other trees, although pure stands are not rare. Its principal associates, besides other hickories, are the oaks, maples, and ashes, chestnut, basswood, and yellow poplar.

The tree is recommended for planting on good soil in the valley of the Ohio River and along its tributaries in Ohio, Indiana, Illinois, Kentucky, and Tennessee. and on fertile hillsides of the Appalachian Mountains.

SILVICAL QUALITIES.

Shagbark hickory grows best in a deep, rich, moist loam. It does well in other moderately rich soils which permit the taproot to penetrate to a moist subsoil, and in the Middle States makes good growth in comparatively well-drained situations wherever it can get the requisite amount of sunlight. It will not thrive in a hard clay soil, or in pure sand, or where a layer of hardpan lies near the surface.

It is intolerant of shade and does well only in the open or when surrounded by other trees which only slightly obstruct the light. When overshadowed, it grows very slowly. Under right conditions

the rate of growth is fairly rapid, comparing favorably with that of white oak.

The tree is subject to the attacks of fungi, which do considerable damage to the leaves and twigs, and numerous insects feed upon it. In recent years a large number of trees have been attacked by the hickory bark beetle, which in some sections has killed nearly all of them. The tree is valuable enough, however, to be worth planting in spite of these dangers.

ECONOMIC USES.

The wood is heavy, hard, very strong, tough, flexible, but not durable in contact with the soil. It is used extensively in the manufacture of carriages and agricultural implements, and for ax and tool handles. There is, in consequence, a good demand for the lumber, at a high price. Second growth hickory, or that which is largely sapwood, is especially esteemed. The wood of the young sprouts is used in making baskets, barrel hoops, and other articles in which flexibility and toughness are required. The wood is also valuable for fuel.

PROPAGATION.

Shagbark hickory reproduces itself both from seeds and from sprouts. Natural reproduction by seed, however, is seldom good, because squirrels eat a large percentage of the nuts, or in mixed stands in the forest the light-loving seedlings are suppressed by other species.

Sprouts from young hickory stumps grow rapidly, and the sprout method of reproduction is advised where an existing plantation or a natural grove of small trees is to be renewed. If good trees are to be produced from stump sprouts, the stumps should be cut low and left smooth and slanting on top. The low stump compels the shoots to start close to the ground, where they can soon form a root system of their own and become self-supporting; while the slant causes rain to run off, and thus prevents decay. All but two or three of the best sprouts should be removed from each stump at the end of the first season. The sprout method is particularly well adapted to the production of small-sized material for hoop-poles and carriage stock.

PLANTING.

On account of the strong taproot which shagbark hickory develops, the cultivation of seedlings in a nursery is advisable only where nuts planted in the field are sure to be destroyed by mice or

squirrels. The best plan is to gather the nuts in the fall, keep them over winter between layers of sand, and plant them in the spring where the trees are to stand permanently. If the nuts are properly handled and not disturbed, from 50 to 75 per cent of them will germinate, but, since rodents are always to be feared, it is well to plant two or three nuts in each hole. They should be planted about 2 inches deep. The growth of the seedlings during the first season should be from 6 to 9 inches.

The spacing will depend upon the object of the plantation; if nuts are the object chiefly desired, wide spacing (about 20 feet by 20 feet) is essential, whereas for a woodlot about 6 feet by 6 feet is right.

Shagbark hickory does well when planted in pure stands, but if the plantation is to be allowed to grow to a considerable age, some other slow-growing species may be mixed with it, or, after it has attained a good growth, it may be planted with a species tolerant of shade. Hemlock and sugar maple are good trees for this purpose.

CARE AFTER PLANTING.

If the plantation is on tillable land, it should be carefully cultivated until the trees become large enough to shade the ground. In any case live stock of all kinds should be excluded and protection against fire should be provided for. If the plantation is attacked by the hickory bark beetle, the infested trees should be cut and the bark should be burned before the middle of May, or advice should be asked of the Bureau of Entomology, U. S. Department of Agriculture.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 24, 1906.

BASSWOOD (TILIA AMERICANA).

FORM AND SIZE.

The basswood is a forest tree which often attains a height of 70 to 80 feet, and a diameter of 2 feet. Under favorable conditions it may be considerably larger. When grown free the tree bears a large, compact crown, which makes a dense shade; in the forest it has a straight stem with but few branches, which are closely clustered at the top. The inner bark (bast), from which the tree gets its name, is fibrous and tough.

RANGE.

The natural range of the basswood is from New Brunswick south along the Allegheny Mountains to Alabama, and westward to eastern Texas, Nebraska, and southern Minnesota. The tree is commonest about the Great Lakes but attains its best development on the bottom lands of the Ohio River, where it is associated with white oak, cottonwood, white ash, black walnut, and hickories. It may be planted on good soils almost anywhere within its natural range; though the most favorable region for economic planting is within the Northeastern States and north of the Ohio River.

SILVICAL QUALITIES.

The basswood is best suited to deep, rich, river bottom soils, and to cool situations. While it will maintain itself on poorer uplands, it is recommended for planting only where the soil is moist and well drained and where droughts are infrequent. It is, in general, a hardy tree. It is moderately tolerant of shade, and the seedlings require some protection from the hot sun. In dry situations it is subject to injury from the sun's heat.

The rate of growth is fairly rapid during early age, being about the same as that of red oak and Norway maple. After attaining maturity the trunk frequently becomes hollow.

The basswood is sometimes attacked by insects, which denude it of leaves or bore into the bark, but serious damage is not frequent. The European species are much more liable to insect injury than the native basswood, and are much less desirable trees generally.

ECONOMIC USES.

The light brown wood is soft, straight-grained, and easily worked but not durable. It is often sold under the name of whitewood, and is largely used for house lumber, woodenware, carriage bodies, panel works, trunks, and paper pulp.

Its large crown and dense foliage render it desirable for planting along roadsides and about the home, and also for low shelterbelts throughout the greater part of its range. Its flowers, which yield great quantities of fine honey, lend it great value for bee keepers.

PROPAGATION.

The basswood reproduces freely both by seed and by sprout. The seed ripen in September or early October, and may easily be collected while attached to their large wings or bracts. They should be separated from the wings and plated at once in nursery beds, as alternate freezing and thawing during the winter rots and loosens the seed coat and causes early germination. If it is impracticable to plant in the fall, they may be kept over winter in a cool, dry place between layers of sand.

The basswood is one of the most prolific among our native trees in sprouts from the stumps, and hence this method of renewing an old stand is recommended. To secure vigorous sprouts the trees should be felled between November and March and the stumps cut low. Sprouts then start close to the ground, where they can soon develop a root system of their own and become self-supporting. All but two or three of the sprouts should be removed at the end of the first season. Under favorable conditions a sprout grows only about a foot the first year.

The basswood seedling develops a single stout root, but this is soon replaced by a number of lateral roots which give the tree a strong hold upon the ground.

PLANTING.

In planting the basswood it is best to use one-year-old seedlings, which should be set out as soon as the frost is out of the ground and before the leaves unfold. As a rule it is advisable to space the trees about 5 feet apart each way.

Basswood does well when planted in pure stands, but it is also of value in mixture with white or red pine (on good soil), or with white elm, white oak, red oak, maple, or hickories.

CARE AFTER PLANTING.

In most situations to which basswood is adapted, little cultivation is needed, since the heavy crowns and rapid growth of the young trees will soon form dense cover, which will exclude grass and weeds, and furnish the proper soil conditions. Where the undergrowth is very rank, however, it is necessary to clear out the weeds in order to give the trees growing space.

Cattle have an especial fondness for basswood boughs and foliage, so that the young trees must be carefully protected from them.

The plantation should be carefully guarded from fire, and should be allowed to assume the character of a forest as soon as it can.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 24, 1906.

BLACK LOCUST (ROBINIA PSEUDACACIA).

FORM AND SIZE.

The black locust (known also as "yellow locust" or often simply "locust") is a forest tree which usually attains a height of from 40 to 60 feet, with a diameter of from 1 to 1½ feet. Under the most favorable conditions it may reach a height of 80 feet and a diameter of 3 feet. In the forest the tree has a clear, straight stem and a small crown. In the open or when grown in plantations the stem tends to divide early, and a more spreading and longer crown is formed. Individual trees, especially when grown in the open, are liable to be bent or twisted by storms.

RANGE.

The natural range of the locust is throughout the Appalachian Mountains from Pennsylvania to Georgia and in certain portions of eastern Indian Territory and Arkansas. It reaches its finest development on the western slopes of the Appalachians in West Virginia.

The locust is found in mixture with other trees of the forest or in pure stands on forest land that has been burned over. On slopes its principal associates are black, red, and chestnut oaks, chestnut, pignut hickroy, and maple. Along streams it occurs with ash, maple, black walnut, and other species.

Theoretically, the range for planting is extensive, covering the region between the Atlantic Ocean and the Mississippi River and

extending west of the Mississippi River south of the thirty-eighth parallel as far as the Rocky Mountains. It is also adapted to the valleys of Utah, Idaho, and eastern Oregon and Washington when planted on irrigated land. The forest plantations to be seen near Salt Lake City, Utah, and Walla Walla, Wash., are among the best in the United States. Recent investigations indicate that the locust can be grown with success in portions of California. Its actual range for economic planting, however, is greatly restricted by the danger of insect injuries.

HABITS AND GROWTH.

The locust grows best on a deep, well-drained, fertile loam, but will grow on almost any soil except a wet, heavy one. It attains an excellent development on limestone formations.

Locust is very intolerant and requires an abundance of light during its entire life. When overshadowed it declines very quickly.

In its native home it is found along streams, on the borders of the forest, or singly and in groups on the steep slopes.

Locust is a rapid-growing tree, but is relatively short lived. In good situations it makes an average annual height growth of 2 to 4 feet and a diameter growth of one-quarter to one-half inch. This rate is sometimes maintained for twenty-five or thirty years, but more frequently the growth becomes slower between the fifteenth and twentieth years. After the fiftieth year growth almost entirely ceases.

THE LOCUST BORER.

The value of the locust is practically destroyed in many parts of the United States by the locust borer, which riddles the trunk and branches. The attack may commence when the trees are very small, and where the borers are numerous the plantation is killed outright within a short time. In localities where the attacks of this insect are slight it is sometimes possible to grow the trees to fence-post size before the plantation is seriously affected. Plantations of locust in Oklahoma, Indian Territory, and in the States west of the Rocky Mountains are almost entirely free from injury by this insect. In most of the States east of the Rocky Mountains planting is restricted or made impossible, according to the local severity of damage by the borer. In case this insect or others seriously injure a forest plantation of locust, the Bureau of Entomology of the Department of Agriculture should be consulted at once.

ECONOMIC USES.

The timber of the locust is extensively used for fence posts, ribs of vessels, treenails, insulator shanks, and vehicles. Its great durability in contact with the soil makes it very valuable for use in the ground, and its toughness and elasticity give it value where great strength is required. The tree is also valuable for fuel, being about equal to bur and white oak for this purpose.

The most common use of locust is for fence posts, for which purpose it has been extensively grown. Because of the large proportion of heartwood the young wood is almost as durable in the soil as the old. Locust posts, under average conditions, will last from fifteen to twenty-five years.

METHODS OF PROPAGATION.

Locust reproduces itself abundantly by seeds and by stump and root sprouts. It extends itself rapidly over old fields and along fence rows. Burned and cut-over lands in the mountains of Pennsylvania and West Virginia are thickly covered with locust seedlings, frequently giving rise to valuable pure stands of this species. The seed is retained on the trees well into the winter and distributed long distances by the strong winter winds. Wherever locust has been planted outside of its natural range the same tendency to spread by seed and root sprouts is exhibited, and young stands killed by fire replace themselves at once by sprouts.

PLANTING.

The seed may be gathered locally by the individual planter or may be purchased from dealers. It may be left in the pods and stored in a cool, dry place for as long as two years without serious harm. If the seeds are removed from the pods, they should be stratified in moist sand in a cool place. Just before planting, the seeds should be soaked for four or five days in water that has been heated to a temperature of 150° to 160° F., which will cause them to swell. Planting should immediately follow the soaking of the seeds, as under no consideration should they be allowed to dry out. The percentage of germination under these conditions is about 50 to 75 per cent.

Spring planting is in general advisable, although the seed can be sown as soon as it matures. The soil of the nursery should be well pulverized, rich, and loamy. If hand cultivation is to be given, the drills may be 12 to 15 inches apart, but if horse cultivation is to be

practiced, rows 2 to 3½ feet apart will give the best results. The seed should not be covered to a greater depth than one-half inch, and the soil should be kept uniformly moist during germination. A pound contains about 29,000 seeds and is sufficient for a row 900 feet long. The seedlings will be large enough to set out in their permanent sites the following spring after planting the seed in the nursery, and in one year they should have attained a height of 1 to 3 feet.

Since the locust has a wide-spreading root system, it requires plenty of room for the proper development of the tree. A spacing of 4 feet apart each way is too close unless very early thinnings can be made and the material utilized for stakes. In the East the trees should be set at least 6 feet apart each way. In the Middle West they should be spaced 4 feet apart in rows 6 feet from each other or 3 feet apart in rows 8 feet apart.

Locust does well in pure stands, but in the semiarid region of the Middle West, where the forest plantation is valued also for its protective character, it may be mixed with Russian mulberry, Osage orange, or green ash.

CULTIVATION AND CARE.

In the Middle West careful preparation of the soil and cultivation for several years after planting are essential for successful growing of the locust. In order to secure a stem that will make straight posts, poorly formed or double-headed trees may be cut back to the ground or pruned two or three years after planting.

Stock should be entirely excluded from the plantation and every precaution taken to prevent fire from running over the ground.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 24, 1906.

WHITE ELM (ULMUS AMERICANA).

FORM AND SIZE.

The white elm is a forest tree which frequently attains a height of from 100 to 120 feet and a diameter of from 6 to 8 feet. Its average size is somewhat smaller, although it is among the largest of our hardwood trees.

When grown in the open the trunk almost invariably divides a short distance above the base, forming a wide-spreading, graceful crown. Forest-grown trees exhibit a wide divergence in form. The trunk is often clear of branches for over two-thirds of its length, straight and gradually tapering, surmounted by a compact crown. At the base the larger trees are often buttressed. The slender, interlaced twigs and the rough, flaky bark, divided into narrow ridges, are typical of the tree in all situations.

RANGE.

The natural distribution of the white elm is extensive. It ranges from Newfoundland to South Dakota and south through western Nebraska to Texas. The tree does not grow in pure stands, but occurs sparingly in mixture with the oaks, ashes, sycamores, yellow poplars, and other hardwoods.

The planting range of white elm is fully as wide as its natural distribution. It may be planted throughout the East and is especially well suited for prairie and plains plantations.

HABITS AND GROWTH.

White elm reaches its best development on deep, fertile, alluvial soil, moderately well drained. The species, however, readily adapts itself to soils less favorable or even to those decidedly poor. It is a hardy tree and will endure great extremes of temperature and moisture.

The elm is somewhat intolerant of shade. Its root system is deep, with an extensive lateral development. It is a fairly rapid-growing tree and often reaches great age. On poor situations both the rapidity of growth and the length of life are reduced.

Although seldom injured by wind, snow, or fungi, the white elm is subjct to damage by insects. Borers often injure or kill the tree, but by far the greatest damage is done by the elm leaf-beetle and other defoliating insects. Because of them the planting of the elm as a park tree has been discontinued in many parts of the country.

It is possible, however, to control the defoliators by early and thorough spraying with an efficient insecticide.*.

ECONOMIC USES.

The wood of white elm is strong, tough, fibrous, and difficult to split, but is not durable. It is in growing demand as a slack-cooperage material, and its use in this industry has resulted in a rapid increase in the stumpage value. The timber is also used for flooring, wheel stock, and shipbuilding, and in the manufacture of agricultural implements.

The hardiness of the species and its indifference to soil conditions make it a very suitable tree for protective planting. For ornamental planting the suitability of the white elm is everywhere recognized. It is probably the most desirable of our hardwoods for such use.

METHODS OF PROPAGATION.

The white elm is a prolific seeder, bearing an abundant crop almost every year. Natural reproduction is usually by seed. European experience has shown that this species sprouts well, but in this country it is not advisable to depend on sprout growth, except from young trees and for the production of small-sized material. The seed ripen in May and should be collected and planted as soon as possible after ripening, since they retain vitality but a short time. It is due to this fact that purchased seeds are often worthless. In all cases home-collected seeds are more satisfactory. The seeds may be gathered by sweeping them up from the ground or by shaking them from the trees into a canvas spread out below.

Plantations should be established with nursery-grown seedlings. The soil of the nursery should be rich, mellow, moist, and fairly well drained. If it is thoroughly worked, no seed beds are required. The seed should be planted in the spring, 60 to 80 seeds per linear foot, in rows 12 to 18 inches apart, and covered with not more than one-eighth of an inch of fine earth. The surface of the rows should be ''firmed'' with a light roller or a board and mulched until the seedlings appear.

There are 93,000 white-elm seeds in a pound, sufficient to plant nearly 1,200 linear feet of seed rows and to produce 20,000 to 30,000 seedlings. With rows 18 inches apart, 1,200 linear feet of drills would require 1,800 square feet for nursery rows. It is not neces-

* For further notes on these insects see Farmers' Bulletin No. 99. Suggestions for the control of borers, scales, and other enemies of white elm will be furnished, on request, by the Bureau of Entomology of the Department of Agriculture.

sary to shade the young plants, although at times partial protection from constant sunshine will be beneficial.

Further information concerning nursery practice is contained in Bulletin No. 29 of the Forest Service, which may be obtained upon request.

PLANTING.

When one year old the seedlings will be 5 to 10 inches high and should be transplanted to the permanent site. The use of older and larger seedlings is sometimes desirable, but in most cases one-year-old plants are suitable for commercial planting. Where the seedling forms a long root this should be cut back to 6 inches and the top pruned correspondingly.

Spacing will vary with local conditions. In general, moderately close planting is necessary to maintain forest conditions during the early life of the stand and to properly shade the ground and protect the soil. A spacing of 6 feet each way usually will prove satisfactory. In later life all stands should be thinned to encourage the best development of the remaining trees.

The white elm thrives in pure stands, but will also grow well when planted with more tolerant species, such as maple, white and red oak, and the ashes. Other trees suitable for planting with elm are black walnut, black cherry, yellow poplar, and basswood.

For prairie planting it is essential that the soil receive thorough preparation. Where there is a heavy sod it should be turned under two or three years before the trees are planted and, if possible, a crop of cereals raised on the ground.

In the East no preparation further than preparing holes in which to plant seedlings is necessary.

CULTIVATION AND CARE.

Cultivation after planting is required only in the case of prairie plantations. In such situations the stand will be much benefited by the better moisture conditions and the suppression of weed growth resulting from cultivation. Eventually the young trees will shade the ground and establish forest conditions.

The young trees should not be planted where there is danger of them being overtopped and suppressed by brush growth and weeds. Plantations should be protected from fire and closely watched to detect the presence of injurious insects.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 24, 1906.

WHITE PINE (PINUS STROBUS).

FORM AND SIZE.

The white pine is the largest of all conifers indigenous to the eastern part of the United States. On proper soils it may reach the age of 250 years or more and attain a height of 150 to 175 feet and a diameter of 3 to 5 feet. The crowns of mature white pines in mixed forests conspicuously overtop the surrounding hardwoods. Mature forest-grown trees are characterized by straight, columnar trunks, destitute of branches for a distance of 75 to 100 feet from the ground, and thin, irregular crowns. At the base of the trunks of old trees the bark is thick and deeply furrowed and of a dark brown color, but becomes thinner and grayish toward the upper part of the tree.

RANGE.

The northern boundary of the natural range of white pine is from Newfoundland west to eastern Manitoba. Through the lake region the range extends west to eastern Minnesota and south to northern Iowa, Indiana, Illinois, and Ohio. In the East it originally occurred throughout New England and the Middle States, and, on the higher elevations of the Appalachians, southward to Georgia and Alabama. It was found in greatest abundance and reached its best development in the St. Lawrence Valley and the lake region. It usually grows in association with hardwoods and other conifers and reaches its largest size in mixture with the former.

White pine may be planted in suitable situations throughout its natural range, but for economic purposes planting should be restricted to nonagricultural lands in New England, Pennsylvania, New York, the Lake States, and the higher slopes of the Appalachians, and should be resorted to only when conditions render natural replacement impracticable, since in many situations, if the land is protected from fire, white pine will extend itself rapidly by natural seeding. Much of the abandoned agricultural land in New England may be profitably planted with this tree, which can be recommended for reforesting burned and cut-over areas generally throughout its economic planting range.

HABITS AND GROWTH.

White pine grows naturally and best in a cool climate on a fresh, light, deep, and sandy soil with a porous subsoil. It readily adapts itself to both dry and moist soils, for it is found on the poorest and

dryest sand and on steep, rocky slopes, and also on moist clay flats and river bottoms, provided the latter are not continuously wet. It is capable of disputing possession with hardwoods, even on fresh, medium-heavy clay and loam soils. It will endure windy and cold exposures, but should not be planted near the seacoast, since it can not withstand strong sea breezes.

White pine can endure considerable shade for a number of years, but as it becomes older it requires more and more light for its development, and after it is 40 or 50 years old the crown demands full sunlight. On this account white pine is best grown in mixture with slower growing hardwoods or other conifers which will not overtop or shade it from above.

In artificial plantations or on abandoned farms which have been reforested naturally, white pine usually grows much faster than in the forest, especially during the early years. Records of plantations in New England show that the average growth of the larger trees ranges from one-fourth to one-third of an inch in diameter annually. It is possible in the eastern portion of the United States to produce saw timber in from sixty to seventy years. Smaller trees suitable for box boards and match blocks can be produced in thirty or forty years.

Owing to the thinness of its bark, young white pine is very susceptible to injury by fire, which must be most carefully excluded from plantations; but between the fifth and twentieth years the greatest cause of injury to the white pine is a weevil which in the grub stage mines in the terminal shoot and causes a crooked stem. Repeated attacks make the tree unmerchantable.

ECONOMIC USES.

The wood of the white pine is soft, light, straight grained, and easily worked, and will not warp. It was formerly used to a great extent for general construction, but on account of its growing scarcity and high price it has been largely superseded for this purpose by other woods. The better grades of this lumber are still used in naval construction—for decking, interior finishing, and spars.

Second-growth white pine is used principally for low-grade lumber, match blocks, box boards, wooden ware, and straight-staved cooperage. Where a demand for this material exists, white pine on nonargicultural lands will prove of economic value. Throughout the manufacturing regions of New England, wherever there is a market for small material, white pine will prove the most profitable conifer that can be grown on poor soils.

Within its range of economic planting white pine forms a very satisfactory windbreak or shelterbelt.

METHODS OF PROPAGATION.

White pine reproduces only from seed. Plantations should be started from nursery-grown stock rather than from seed, which usually gives unsatisfactory results.

If only a few hundred plants are desired, it usually is cheaper and easier to buy them from a nerseryman than to raise them, but if several thousand plants are needed it will be cheaper to raise them from seed. Purchased stock should be secured in the early spring before planting time, and upon receipt should be unpacked immediately and the roots dipped into a bucket containing thin mud. The trees should then be heeled-in in a shady place to await planting time, care being taken that the foliage does not become covered.

If the trees are to be grown in a home nursery, the seed may be purchased, but a large saving may be made by collecting it in the neighborhood, if this can be done. Cones should be gathered during the latter part of August or in September, before they begin to open. They may be picked from standing trees, or from felled trees if lumbering operations are being conducted nearby. When gathered, the cones should be spread out on a sheet or floor, where they will be exposed to the sun, yet proteced from wind and rain. Within a week they will open and allow the seed to drop out. A thorough stirring will separate the seed; after which the cones may be raked away. One bushel of cones will yield from one-half a pound to 1 pound of clean seed, which will average from 29,000 to 30,000 seeds per pound. Seeds may be stored over winter by placing in small sacks and hanging the sacks in a cold, dry place.

The most successful method of raising seedlings is by sowing the seed in nursery beds. Seed beds should be composed of fine, loose, fairly fertile soil, moderately moist but always well drained. The soil must not be too rich; otherwise the seedlings will suffer when transplanted to the less favorable conditions of the permanent site.

A convenient size for seed beds is 4 by 12 feet, with a path about 18 inches wide between the beds, so that the plants can be weeded and cared for with ease. The seed should be sown in drills, 4 to 6 inches apart, and lightly covered with fine earth. Sowing should not begin until the ground is warm enough to cause rapid germination. Seed may be safely sown at the time garden vegetables are

planted. After a seed bed is sown the surface should be "firmed" with a board or light roller.

The plants will begin to appear in from three to five weeks. Like other conifers, they will require partial shade during the first season, but subsequently can endure full sunlight, especially in New England. A shade frame of lath supported 18 inches above the bed will serve the purpose.

One pound of white-pine seed is sufficient to sow 500 linear feet of seed drill, or about 200 square feet of seed beds, with drills 6 inches apart. Even with proper care some seed may fail to germinate promptly, but about 10,000 plants may be expected for every pound of fertile seed sown. White-pine seed retains its vitality for several years, and when kept in cold, dry storage a fair percentage has been known to germinate after five years. Fresh seed, however, is always to be preferred.

Two years after sowing, the seedlings should be transplanted in the spring from the seed beds to nursery rows, in order to develop a good, fibrous root system. They may be set out 3 inches apart, in rows from 12 to 18 inches apart. The roots should be set slightly deeper than they were before. The best method of transplanting is to open a shallow trench of the proper depth with a spade and set the plants by hand, carefully covering the roots of each plant with fine soil and gently firming it. Transplants, if thoroughly cultivated and weeded, will be ready for final planting at the beginning of the fourth season. At this age they should be 6 to 9 inches in height and have a well-developed system of fibrous roots.

In the early years of the white pine a very injurious fungus must be guarded against. If the soil becomes soaked, or sufficient light and air are withheld, ideal conditions for the action of the fungus exist, and the usual result is the "damping off" of large numbers of the young trees. In shaded seed beds, when the quantity of rain is sufficient to endanger the young trees, the "damping off" may be checked by so raising one side of the shade frame that it acts as a partial roof. Dry sand sprinkled over the seed bed will usually tend to hold the fungus in check.

Birds and field mice are often very troublesome around coniferous seed beds. If danger from such sources is expected, the seed may be coated with red lead mixed with linseed oil before sowing. This is distasteful to most birds and rodents and is usually quite effective. Another method is to protect the beds by netting and similar devices until the seedlings are sufficiently developed to be free from danger.

PLANTING.

White-pine seedlings should be planted on the permanent site in the early spring when the ground is dry enough to work. In most cases the site will not need preparation previous to planting.

The roots must not be allowed to become dry during the planting. Even brief exposure of the roots to the sun and air will cause the plants to die.

The distance apart at which the trees should be planted depends upon the character of the site and whether the pines are to be planted in mixture with other trees or in a pure stand. The usual distance is 6 by 6 feet apart.

In pure plantations white pine produces excellent forest conditions, but it is also adapted to growth with a number of other species of which chestnut, European larch, Norway spruce, red oak, and hard maple are the more important. Chestnut is a very desirable tree for mixture with white pine on well-drained soils which are not calcareous, but since the planting range of chestnut does not, except in Vermont and New Hampshire, extend above the forty-second degree of latitude, it can not be used in mixture except within a limited area. In Pennsylvania, Michigan, Wisconsin, Minnesota, and northern New York white pine may be mixed with European larch, Norway spruce, or hard maple, and on soils adapted to red oak the latter may be used to advantage. In mixture with chestnut or European larch white pine should constitute at least two-thirds of the stand, spaced according to the following diagram:

[6 feet by 6 feet.]

P	P	S	P	P
P	S	P	P	S
S	P	P	S	P
P	P	S	P	P

P=white pine. S=chestnut or European larch.

Mixed with other species, the stand should be composed of an equal number of white pine and the associated species planted alternately.

CULTIVATION AND CARE.

The cultivation of white pine in plantations throughout the eastern part of the United States is unnecessary. Persistent dead branches should be removed when possible, but it is not advisable to prune live ones. Where there is a demand for small material, the stand may be profitably thinned at the age of 20 to 30 years, removing at this time all suppressed or intermediate trees which are not needed in the stand to shade the ground or to assist in naturally developing the large trees.

Fire must be kept out of stands, since the bark of young trees is thin and easily damaged, and injuries from this source cause rapid decay.

Information regarding general nursery practice and planting may be obtained from the publications of the Forest Service, which will be forwarded upon request. Insect damage should be reported promptly and specimens mailed to the Bureau of Entomology of the United States Department of Agriculture, where they will be identified and measures suggested for their control.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 24, 1906.

CHESTNUT (CASTANEA DENTATA).

SIZE AND FORM.

The chestnut is among the largest of our hardwood trees, and in the region of its best development has been known to reach a height of 120 feet and a diameter of great size. Throughout the greatest part of its range, however, it is much smaller, with an average height of 80 to 100 feet and a diameter of from 2 to 4 feet. When grown in the forest it forms a tall, clean, fairly cylindrical trunk; in the open it assumes a form like a fruit tree, with a short, thick trunk and a broad, spreading crown. The bark is thick and deeply ridged, and the root system is extensive, in both lateral and vertical development.

RANGE.

The chestnut is distributed throughout the eastern part of the United States at elevations varying from sea level in Massachusetts to 5,000 feet in North Carolina. It ranges from southern Maine southward through New England, but in this region is most abundant in the lower valleys of the Merrimac and Connecticut rivers.

Except near the sea, it is common in Rhode Island and Connecticut and as far south as Delaware. It is found also in the Province of Ontario and in the Eastern States, especially in New Jersey, Pennsylvania, and parts of Maryland. Further south it is found along the Appalachians to Alabama, growing well in all soils above 2,000 feet in elevation, but less abundantly below. In the Middle West it is confined to Michigan, Indiana, and Illinois.

Large areas throughout the East, particularly in New England, New York, Pennsylvania, and Maryland, are well adapted to chestnut. Outside of its natural range, however, the success of this species is doubtful. Chestnut can be grown fairly well throughout Missouri and southeastern Iowa, in the eastern counties of Nebraska and Kansas, and in the southern half of Minnesota, but nowhere on prairie soil is it long-lived or of first-class growth. In Colorado it grows well under irrigation, and would probably succeed in other parts of the West if well watered. If it is planted too far north the shoots fail to become woody before they are nipped by the early frosts. The tree will endure the heat and cold of its natural home and will remain thrifty in sunny, dry situations, but is very susceptible to injury from hot winds.

HABITS AND GROWTH.

Chestnut will thrive on a variety of soils, from almost pure sand to coarse gravels and shales. On limestone soils, however, it nowhere makes good growth. In general it prefers the dry, well-drained, rocky land of the glacial drift to the richer, more compact alluvial soil of the lowlands. Chestnut does not need a rich soil so much as one whose physical structure insures good drainage. Light is essential to the tree, since it is somewhat intolerant of shade.

Few of our valuable hardwoods are more rapid in growth than chestnut. Seedlings usually attain a height of from 10 to 15 inches at the end of the first season. From then until the thirtieth year the annual height growth will average from 15 to 20 inches. Coppice sprouts make even more rapid growth during the same period, but in later life their growth falls of rapidly.

Ordinarily the chestnut, as a forest tree, is little troubled by insects or fungi. Several forms of borers work in the wood and under the bark, and their ravages are sometimes extensive. The nuts are attacked by the larvæ of two or more species of weevil, but to the timber grower this is not serious. Trunks of the young trees in warm situations are sometimes affected by a body blight or "sun

scald." The bark cracks and loosens on the south and west sides of the tree, and the affected portion finally dies. The extent of injury from this source is, however, not great. During the past ten or fifteen years a new disease of unknown cause has been doing considerable damage.

ECONOMIC USES.

Chestnut timber is in great demand. The wood is light, moderately strong, coarse grained, and elastic. It works easily and is very durable in contact with the soil. In seasoning, the wood often checks and warps, but damage from this source is not serious. It is used in cabinet work and cooperage, and for fence posts, telegraph and telephone poles, ties, and mine timbers. The presence of tannin in the wood increases the demand for small-sized and inferior material, and large quantities are used in the manufacture of tanning extracts.

Except in portions of the Southern Appalachians, very little of the original chestnut remains, but the coppice reproduction is so rapid that a considerable supply of small-sized timber is still available. The excellent qualities of the wood insure a permanent demand and good price.

METHODS OF PROPAGATION.

Chestnut plantations may be established by direct seeding or by the use of nursery-grown seedlings. Seed may be purchased, or collected from trees in the vicinity. To prevent drying out and consequent loss of germinating power, collected seeds should be kept stratified in moist sand until the following spring.

Home-grown seedlings are usually superior to those purchased from commercial dealers, and are much cheaper. The nursery should be located on fresh, well-drained, fertile soil, under conditions such as are usually present in an old garden spot. Thorough cultivation of the soil is required, but the preparation of seed beds is unnecessary.

Seed should be planted, 10 to 12 per linear foot, in nursery rows 18 inches apart. Care should be taken not to cover the seed more than 1 inch deep.

A bushel contains 6,500 to 8,000 nuts, sufficient to plant 650 linear feet of nursery rows and to produce at least 4,000 plants. These rows will cover an area of 975 square feet. While in the nursery, seedlings require careful cultivation and should be kept entirely free from weeds.

PLANTING.

When planting on permanent sites the trees should be set 5 or 6 feet apart, each way, the width depending upon the quality of the site and the possible market for the product of thinnings. In good situations the wider spacing is advised.

If the trees are to be grown directly from seed without transplanting, seed spots should be prepared, spaced as above. Two or three seeds should be planted in each and covered about 1 inch deep with fine earth. Only one tree should be allowed to remain in each hill. This method is recommended by many, and where there is no danger of squirrels it will prove satisfactory and less expensive than the use of seedlings. In general, however, the seedling plantation will be safer and will give better results.

The system of management best suited to the chestnut is the pure coppice, with a rotation of from twenty-five to thirty-five years. Coppice makes more rapid growth than seedling forest, and produces timber in many respects superior. The species also grows well in mixtures, particularly with the white and red pines and the European larch, and also with the oaks, ashes, and maples.

CULTIVATION AND CARE.

On the prairies, plantations should be cultivated until the young trees are well established, but in the East cultivation is unnecessary.

If insects appear in alarming numbers in the forest, specimens, together with an account of their habits, should be sent to the Bureau of Entomology of the Department of Agriculture for identification and suggestions as to their destruction or control.

The greatest enemy of the chestnut, as of other forest trees, is fire, from which it should at all times be fully protected.

Approved: JAMES WILSON, Secretary.
Washington, D. C., November 24, 1906.

COTTONWOOD (POPULUS DELTOIDES).

FORM AND SIZE.

The cottonwood is naturally a tall, straight tree, and under favorable conditions may attain a height of 75 to 100 feet and a diameter of 2 to 3 feet. When grown in the open or in single rows it develops a large, wide-spreading crown and a short, heavy stem. In dense stands, however, the crowns become narrow and oblong and the stems long, slender, and free from branches.

The Carolina poplar, which is considered a horticultural variety of the common cottonwood, is widely used as a shade tree. It is not easily distinguished from the true cottonwood.

RANGE.

The eastern boundary of the natural range of cottonwood extends from central Quebec southward through northwestern New England, western New York, and western Pennsylvania; thence, south of the Potomac River, through the Atlantic States to western Florida. The western boundary extends from southern Alberta, in Canada, southward along the Rocky Mountains to northern New Mexico.

The cottonwood occurs usually in pure stands or in mixture with willow and other moisture-loving trees. On soils of the flood plains of the Mississippi River in western Kentucky and Tennessee, which are especially favorable, it forms a part of the mature hardwood forests.

For economic planting the range is confined to regions throughout the Middle West where there is a permanent supply of water near the surface.

HABITS AND GROWTH.

The most favorable site for cottonwood is the alluvial soil along water courses, for the most important factor in its growth and development is the available moisture in the soil and not the fertility. Forest plantations of cottonwood require a situation in which the water table is within 10 to 15 feet of the surface. Individual trees. or single rows, however, on account of their extensive root system, can maintain themselves in drier situations. So many failures have resulted from attempts to establish cottonwood groves on upland soils that it is usually considered impossible to grow the tree except in rows along highways and similar places. So planted, the trees are valuable for windbreaks and give good returns in fuel and re-

pair material. However, more satisfactory results will be secured by planting in permanently moist situations if production of lumber is desired.

Abundant light is required for development, and young stands tend to become thin. The crown cover is frequently so sparse that grass and shrubs come in under the trees and check growth. This drawback can be prevented by underplanting the grove with shade-enduring trees.

Growth in early life is very rapid. Small trees in a single year may increase from 3 to 5 feet in height and from 1 to 3 inches in diameter. Between the ages of 10 and 15 years the rate of growth gradually lessens, and under certain conditions maturity is soon reached.

Cottonwood is comparatively free from insect pests, though leaf insects occasionally do serious damage. In case of severe attacks application should be made to the Bureau of Entomology of the Department of Agriculture for information in regard to methods of control.

ECONOMIC USES.

The wood of cottonwood is light and soft. It is not strong, and it decays rapidly in contact with the soil. Regional factors of climate and soil cause marked differences in quality. In western Kentucky and Tennessee, for instance, the so-called yellow cottonwood furnishes a much better grade of wood than in the Missouri River region. The wood has a tendency to warp in seasoning, but this may be overcome by proper methods of piling.

Paper pulp, box boards, backing for veneer, the unexposed parts of furniture, wagon boxes, interior woodwork and boarding, and fuel are the principal products for which the wood is used. The increased value which the tree is gaining for these uses, coupled with the ease and rapidity with which it can be grown, renders it one of the important species for commercial planting in the Middle West. Its fuel value in some regions is especially high, since it furnishes a greater amount of wood in a given time than other species. In proportion to volume the relative heat production is, however, low.

Cottonwood is useful for protecting agricultural lands subject to annual overflow. A narrow belt of trees on the river side of such lands protects the fields from debris and checks the erosive action of the water. Plantations of cottonwood established on land between the river and the levee will not only protect the levee from damage

by wave wash caused by the wind, but will also give large commercial returns. It is also particularly adapted for planting along canals, since the roots do not grow into the water.

METHODS OF PROPAGATION.

Cottonwood seeds abundantly and extends itself rapidly over newly made land along rivers. The seed ripens in May or June, and unless it falls on a favorable situation it quickly loses its ability to germinate.

Propagation by seedlings or cuttings may readily be carried on. Large numbers of seedlings annually spring up on the sand bars, where 1-year-old trees for esablishing a plantation can be easily and cheaply procured. A plantation may be established rather more cheaply by cuttings than by seedlings. The cuttings should be made from 1 to 2 year old branches of vigorous trees. Cuttings one-half inch in diameter and 18 to 24 inches long are of desirable size for ordinary use. Much larger cuttings, however, can safely be used and are often desirable where the erosion is very severe.

PLANTING.

Seedlings or cuttings of the cottonwood should be set out in the spring as soon as danger from severe frost is past. In the middle West this time ranges from the latter part of March to the first of May.

Seedlings may be quickly and cheaply planted by a man and a boy working together. With a spade the man makes an opening in the ground into which the boy slips a tree. The spade is then withdrawn and the soil about the tree firmed immediately, before the man advances for the planting of the next one.

Two-thirds of the length of the cutting should be below the surface of the ground, and on the portion above the ground there should be at least two or three good buds.

In planting groves on permanently moist situations the trees should be set 6 to 8 feet apart each way. This gives 1,210 or 680 trees per acre.

CULTIVATION AND CARE.

The growth of the cottonwood is so rapid where conditions are at all favorable that it is seldom, if ever, subject to the crowding or overtopping of less desirable species.

Plantations should not be used for pasturage for at least five years. Grazing animals not only eat the tender shoots and leaves,

but expose and cut off the roots by trampling the ground around the trees.

Fire is one of the most serious enemies of this tree, both in planted groves and natural forests. Protection can readily be secured by plowing several furrows around the plantation. If the furrows are kept free from weeds, fire will be effectually kept out. Where this is not possible a path or fire lane entirely surrounding the plantation should be raked free of leaves and debris. In the spring and fall, when the danger from fire is greatest, the plantations should be kept under observation, and all fires should be extinguished immediately.

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HARDY CATALPA (Catalpa speciosa).

FORM AND SIZE.

The hardy catalpa is a tree of medium size, with slender branches forming a spreading, round-topped head. Under average conditions it grows to be from 50 to 70 feet high. In the forest it is straight and tall, and occasionally attains a height of more than 100 feet and a diameter of from 2 to 4 feet. Because of its frequent failure to form a terminal bud the catalpa has a tendency to crooked growth, and sometimes develops a short trunk with large branches close to the ground.

RANGE.

The hardy catalpa in its natural range was confined to a very limited region, extending from the valley of the Vermillion River, in Illinois, through southern Illinois and Indiana, western Kentucky and Tennessee, southeastern Missouri, and northeastern Arkansas. It was apparently distributed by backwaters along the overflow lands of the Wabash River, up nearby creeks, and down the Ohio and Mississippi Rivers as far as New Madrid, Mo. In southeastern Missouri it meets the common catalpa *(Catalpa catalpa)*. The latter species is indigenous to southwestern Georgia, western Florida, central Alabama, and Mississippi, but is widely naturalized and cultivated east of the Rocky Mountains, growing as far north as eastern New England.

The hardy catalpa has been planted as far north as Turner County, in South Dakota, southern Minnesota, southern Michigan,

and southern Massachusetts, and westward to eastern Nebraska, central Kansas, and central Oklahoma. It has done well on irrigated lands in New Mexico, Colorado, and Utah, at the lower altitudes, and where the soil is free from alkali. The present range for economic planting is on the fertile alluvial lands of the middle West, south of the forty-first parallel of latitude. Catalpa plantations have been especially successful in the southern portion of Ohio, Illinois, and Indiana; in Nebraska south of the Platte River and east of Adams County, and in eastern Kansas.

HABITS AND GROWTH.

Catalpa requires a deep, fertile, porous soil for good growth, and it can not succeed on heavy, poorly drained land. It grows well on prairie soils and even where there is considerable sand, provided overflows are frequent or permanent water is within 10 or 15 feet of the surface. It is not adapted to poor sandy or stiff clay soils, or to those which have a tenacious gumbo subsoil. However, if a layer of clay which is not too heavy occurs beneath several feet of good soil it is of advantage, since it forms a beneficial soil foundation, retaining fertility and moisture. Catalpa will not tolerate a strongly alkaline soil. An annual rainfall of at least 25 inches is necessary for the best growth of the tree, unless it can send its roots down to the water table. Commercial plantations especially demand a good soil. It has been proved that the returns realized from a crop grown on the best soil are proportionately very much greater than those obtained from poor land in the same locality.

The hardy catalpa is very intolerant, and in dense stands the lower side branches are killed by the shade. If they become more than half an inch in diameter they cling to the tree for years after they die, thus delaying the complete pruning of the bole. New wood is deposited around the dead branch, but does not close tightly about it. The holes thus formed by the persistence of dead branches lead straight into the heart of the tree and conduct the germs of decay into the trunk. If fungus spores gain entrance, the heart decays and eventually the tree breaks down. The tendency to crooked growth and the failure to shed its limbs properly are the two most troublesome characteristics of the catalpa.

The hardy catalpa matures early and under cultivation is one of the most rapid-growing trees planted in the West. A height growth of 2½ feet and a diameter increase of one-half inch annually for

the first ten to fifteen years are not unusual. It does not, however, often attain dimensions that fit it for saw logs.

Some of the trees in a plantation will be of suitable size for posts when from 8 to 10 years old, and five or six years later the entire crop should become merchantable. Good telegraph poles are grown in from twenty to thirty years, according to the adaptability of the soil for this species.

The hardy catalpa is, as a rule, free from destructive diseases. It is subject to severe attacks of leaf-eating insects, and a number of parasitic fungi often cause considerable damage to the foliage. Root rot is rare. The wood is quite resistant to decay-producing fungi. The wood of living trees is destroyed by two fungi, one of which causes a soft rot and the other a brown rot. The soft rot is common, the other only occasional. The soft-rot fungus enters the tree through the holes caused by rotting branches and destroys the heartwood very rapidly. The wood is changed to a soft, spongy mass incapable of standing any strain, so that broken trees are common in infected plantations.

ECONOMIC USES.

The rapid growth, durability in contact with the soil, lightness, elasticity, and high fuel value of catalpa wood make the tree one of the most valuable for economic planting. Catalpa wood cut from the living tree is probably immune from attack by fungous diseases, and is one of the most durable timbers known. When used for fence posts it often remains sound for thirty to forty years. Even in young trees nearly 75 per cent. of the wood is heartwood, so that when used for posts the decay of the sapwood does not materially affect the value of the post. The rich coloring of the wood makes it also well suited for cabinetwork.

The catalpa has been planted principally for fence posts and small telegraph poles. A few plantations have been made for the production of the railway ties. The desirability of growing catalpa for ties has not yet been established. Experience thus far has shown that plantations can be managed most profitably on a short rotation of from fifteen to twenty years for the production of posts or small poles.

The catalpa has unfortunately been discredited in many localities because of poor results from early plantations. These were in very many cases due to the substitution of an inferior species of a hybrid for the true hardy catalpa. While the quality of the wood

is somewhat similar, the common catalpa and its hybrids are much less hardy than *Catalpa speciosa,* are less erect in habit, and have a marked tendency to branch low.

METHODS OF PROPAGATION.

The catalpa reproduces by seed and by sprout from the stump. In starting a commercial plantation seedlings should be used, and these may be grown at home at comparatively small cost.

Seed may be purchased, but it is advisable for the planter to collect his own supply, if possible, since seed from certain undesirable species, more prolific than the hardy catalpa, has been sold extensively by dealers as genuine. The seed ripens in the autumn and the pods ordinarily hang on the trees all winter. It is well, however, to gather the pods as soon as the leaves fall, since some of them are likely to open and drop their seeds. The seed should be kept over winter in the pods, in cool, dry storage. Sowing should be done early in the spring, but not until the ground has become warm. Drills should be made in well-prepared, mellow soil, and the seeds sown a half inch apart and covered to a depth of about 1 inch. The rows should be far enough apart to allow thorough cultivation. Under average conditions the seedlings will grow 12 to 24 inches in height during the first summer, and will be suitable for planting the following spring.

One pound of hardy catalpa seed contains nearly 20,000 seeds, which will be sufficient to sow about 8,000 linear feet of drills. Between 40 and 75 per cent. of the fresh seed should germinate, and a pound may be expected to produce about 12,000 one-year-old plants.

PLANTING.

The planting site should be prepared by plowing and harrowing in the spring, and there is an advantage in growing a field crop on the site for one season before planting. It is usually advisable to plant one-year-old stock in the spring. In the South, however, where the winters are mild, catalpa may be planted with safety in the fall, after one season's growth in the nursery.

Proper spacing of the trees in the planation depends to some extent upon regional and site conditions. East of the Mississippi catalpa may be planted 6 by 8 feet or 8 feet apart each way, but in the plains region it will be well to set the trees 4 by 8 feet or 6 feet apart each way. A spacing of 4 by 4 feet is advisable only when early thinning can surely be made. In general this very close spac-

ing should not be used, because the catalpa requires considerable room for lateral root development, and crowding will tend to lessen the vitality of the trees and to lower the rate of growth.

In raising catalpa the object is to obtain the best growth and most perfect form in the shortest possible time. To accomplish this a relatively wide spacing of the trees, supplemented by a limited amount of artificial pruning, is necessary.

While catalpa has thus far been planted chiefly in pure stands, an associate tree may prove desirable in the Middle West. This should be of a tolerant species and slower growing than the catalpa. This associate tree, or "filler," would complete the crown cover and would assist in pruning the catalpa and in forcing straight upward growth. Two species that are well adapted for planting with catalpa in the West are Russian mulberry and Osage orange.

CULTIVATION AND CARE.

Catalpa requires especial care if the best results are to be secured. Waste land and rocky hillsides are not suited to catalpa growing. In forest planting for profit such sites should be planted with saw-timber species and the catalpa confined to some area of good arable land, set aside expressly for the production of fence posts and small material.

It is usually advisable to cultivate plantations during the first three seasons, although in regions of abundant rainfall they may be planted with cowpeas or soy beans or sown to crimson clover after one season's cultivation. The disk harrow is the most suitable implement for the first cultivation, after which a common harrow may be used. The soil should be stirred often enough to maintain a good dust mulch for conveying moisture. After the first year cultivation should be shallow, so as not to mutilate the roots of the trees, and during the third season it may not be feasible at all, since by that time the ground between the rows will often be filled with a network of roots.

Except in the South, on rich soils, where height growth is especially vigorous, the young trees should be cut back to the ground during late winter or early spring after one or two seasons of growth in the plantation. A number of sprouts will spring up from the stump during the following spring, all of which should be removed during the early part of the growing season except the most vigorous one. Care should be taken not to tear the bark when removing the sprouts. The surviving stem should make a straight

branchless growth of from 6 to 10 feet the first season, and and will largely do away with the necessity of pruning. Cutting back offers the simplest means of producing straight trunks, and without retarding ultimate height growth, it accomplishes the same object as pruning at less expense.

If pruning is undertaken it should be done late in the winter or in early spring before growth starts. In no case should catalpa trees be pruned to a whip. All trees which become severly injured in any way, as by wind, fire, or animals, should be cut back to the ground without delay.

In case the trees have been planted as closely as 4 feet apart it will be necessary to commence thinning the plantation in about four to six years, and before any of the stems will be marketable except for stakes. If, however, a wider spacing has been used and proper care and attention given the plantation, thinnings will not be needed until eight to ten years after planting, when many of the trees will yield one or two posts each.

Between the ages of 15 and 20 the entire plantation may be cut clean for posts and a new forest allowed to start from the stump sprouts, or it may again be thinned and the best trees left standing to produce poles. If this latter plan is followed, however, the stump sprouts are likely to be less vigorous than if all the trees were cut.

In the Middle West the catalpa is often injured by strong, steady winds, which whip off the leaves, dry out the soil, and cause crooked and deformed growth. Plantations should, therefore, be protected by setting out several rows of hardier species along the exposed sides, a mixture of species being best. A good combination would be two rows of Russian mulberry or Osage orange adjoining the plantation with a row of cottonwood on the outside. The mulberry should be spaced 4 by 4 feet and the cottonwood 8 by 8 feet.

If protection from fires is necessary, it should be given by plowing a fire guard of half a dozen furrows around the plantation each year. If the plantation is large, it is better to divide it into blocks of 40 to 50 acres each by means of lanes 15 to 20 feet wide. These lanes should be kept plowed, so that fire can not spread from one block to another. This system also gives easy access to the interior of the plantation.

Soft rot of the catalpa can not be checked after a tree is infected, but proper treatment of the plantation will prevent it. Trees that are only partially rotten may be cut and used for posts, since the

fungus ceases to work as soon as the tree is cut. Methods of planting, cutting back, or pruning which produce a clean, straight growth of the tree free from low side branches give the fungus no chance to enter unless a wound is caused in some unusual way.

If the plantation is threatened by insect attacks, specimens should be sent to the Bureau of Entomology of the Department of Agriculture for identification and advice as to remedial measures.

RETURNS.

Catalpa has been planted under such a wide range of conditions that the returns have not been at all uniform. Profits from catalpa growing depend most upon the suitability of the planting site, upon proper spacing, and especially upon the cultivation and care of the plantation.

The following figures on the yield of hardy catalpa under a variety of conditions indicate in a general way the returns which may be expected from plantations:

Two plantations in Marion County, Mo., in which the trees were spaced 4 by 8 feet when set out, contained, respectively, 392 trees and 616 trees per acre at the end of twenty years. The average height of the trees in the first grove was 47 feet, with a diameter, breast high, of 7.5 inches; those in the second grove were 55 feet, with a diameter of 7 inches. The products per acre of the first grove were 1,568 first-class posts, 392 second-class posts, and 1.9 cords of fuel wood; of the second grove, 3,038 first-class and 616 second-class posts, and 4.8 cords of fuel wood.

A plantation in Sangamon County, Ill., in which the original spacing was 4 by 5 feet, contained at 21 years of age 800 trees, with a yield per acre of 1,920 posts, all first class, and 4.9 cords of fuel wood. The cost of establishing a plantation in Illinois under present conditions is about $15 per acre.

A 17-year-old plantation in Washington County, Iowa, in which the trees had been set 4 feet apart each way, was found to contain 1,312 trees per acre over 4 inches in diameter breast high. The average diameter of these trees was 5.7 inches, and the estimated yield of the stand was 2,778 first and second-class posts per acre. The effect of the quality of the soil upon the yield of catalpa is well shown by a 21-year-old plantation in Iowa County, Iowa. The original spacing of the trees was 9 by 5 feet, and on good soil there remained 524 trees per acre which had a diameter of 4 inches or over breast high. The estimated yield was 1,896 posts and 96 poles.

A portion of the stand which was growing on a sandy knoll contained only 380 trees per acre, with a yield of but 572 posts.

A 25-year-old plantation in Nemaha County contained 747 dominant trees per acre, with an average diameter breast high of 6.6 inches, and an estimated yield of 1,829 first-class posts, 845 second-class posts, and 1.9 cords of wood.

In York County, Neb., which is near the western limit of the range for economic planting, a 21-year-old plantation contained 406 dominant trees per acre. The average diameter of the trees was 4.7 inches, and the yield was limited to 242 first-class and 140 second-class posts, and 0.4 cord of wood.

In a plantation in Pawnee County, Neb., the owner kept a strict account of all expenses incurred in establishing, maintaining, and harvesting his plantation, and of the final proceeds. The seedling trees, at $1.15 per thousand, cost $3.13 an acre; the preparation of the ground, planting, cultivating, and pruning cost $18.46—a total of $21.59 per acre. At 5 per cent. compound interest this was increased, in the sixteen and one-third years during which the plantation grew, by $26.34. Cutting and marketing the crop added $61.90 per acre to this, so that the full cost at the end of the experiment for the 20 acres was $2,196.

The returns were:

31,397 third-class posts, at 5 cents	$1,569 85
17,349 second-class posts, at 10 cents	1,734 90
4,268 first-class posts, at 12½ cents	533 50
270 first-class posts, at 15 cents	40 50
211 8-foot posts, at 20 cents	42 20
9 10-foot posts, at 25 cents	2 25
4 10-foot posts, at 30 cents	1 20
258 10-foot posts, at 35 cents	90 30
41 12-foot posts, at 40 cents	16 40
167 14 and 16-foot poles, at 50 cents	83 50
Total for posts and poles	$4,114 60
214 cords of woods, at $5.25	1,123 50
Total income from 20 acres	$5,238 10

The total profit was, therefore, $3,042.19, or $152.17 per acre, equal, with allowance for 5 per cent. compound interest, to $6.24 an acre.

RUSSIAN MULBERRY (MORUS ALBA TATARICA).

FORM AND SIZE.

The characteristic form of the Russian mulberry is low and bushy. When grown in the open very little of the trunk is free from branches, and even when grown in a close-spaced plantation severe pruning is required to produce a straight undivided trunk. On good soil the Russian mulberry usually attains a size of 30 or 40 feet in height and 1 foot in diameter.

RANGE.

The Russian mulberry is a hardy variety of the Asiatic white mulberry. It was introduced into the United States by the Russian Mennonites about 1875, and was subsequently distributed widely throughout the middle Western States. The range for its economic planting is southern Nebraska, southern Iowa, Kansas, Oklahoma, and Indian Territory. It can not endure the severe winters of the Dakotas; the leading shoots are occasionally frozen back in Kansas.

Where it has escaped from cultivation it occurs with the oaks and maples, preferring the bottom to the upland.

HABITS AND GROWTH.

The Russian mulberry will grow both on sandy and on clay soils, but does best on rich loam where the water table is from 10 to 15 feet below the surface. It will endure almost any amount of drought and neglect. Even in dry situations growth is fairly rapid. These qualities adapt it both to upland and valley situations in the semi-arid regions. It is decidedly tolerant of shade, and can therefore be used to advantage for under-planting or for mixing with a more rapid-growing species to increase the height growth and to induce natural pruning of the latter.

Height and diameter growth are fairly rapid. On very favorable sites a height of 20 feet and a diameter of 8 inches are not unusual for a tree 10 years old.

The tree has comparatively few enemies. It is not in any degree susceptible to the attacks of fungi, but the foliage is sometimes attacked by defoliating insects.

ECONOMIC USES.

The Russian mulberry serves a number of useful purposes. If close-planted and severely pruned, the Russian mulberry is useful for the production of posts and fuel. On favorable sites it will produce fence posts in ten to fifteen years. The wood is rather heavy, elastic, coarse-grained, and moderately strong. It splits easily and, when seasoned, makes a durable fence post, which is probably its most valuable use. The fuel value of the wood is high.

While the fruit is of an inferior quality, it is much used for domestic purposes in the absence of better kinds. Many horticulturists have established mulberry windbrakes around their orchards. The natural form of the tree makes it well suited to form a low, dense windbreak, if left unpruned. The windbreak, aside from its protective value, furnished food greatly relished by birds, and they are thus less likely to eat more valuable fruit in the orchard.

PROPAGATION.

Reproduction of the Russian mulberry takes place both by stump sprouts and by seed. Renewal after cutting is a simple matter; all that is necessary is to remove the surplus sprouts and give the best one a chance to develop. A quick-growing stump sprout will have better form than the original tree. Plantations can be started from cuttings, but propagation from seed is easier and produces better plants.

Fruit is borne abundantly. The seed may be separated by crushing and washing the berries. After drying, the seed should be kept in a cool, dry place until a week or ten days previous to sowing. The seed may be sown as soon as it ripens, but generally the better practice is to wait until the following spring, so that the seedlings will have an entire season in which to grow before the coming of cold weather. The seed should be sown in fresh, fertile soil, and covered not more than one-half inch. About one to two weeks are required for germination. Better results are obtained by mixing the seed with moist sand and keeping the mixture in a warm place until germination begins. The sand and seed can then be sown together on a well-prepared bed. The bed should be covered with one-eighth inch of sifted loam. The growth during the first season will be enough to bring the trees to proper size for transplanting to the permanent site the following spring.

PLANTING.

The Russian mulberry should be spaced close in plantation, in order to overcome, as much as possible, its inherent tendency to branched and crooked growth. For windbreaks, consisting of one or two rows, the trees may be planted at 2 or 3 foot intervals, and in plantations they may be spaced 4 by 4 feet or 4 by 6 feet. The Russian mulberry is found more often in mixed than in pure plantations. Its ability to thrive under partial shade makes it well suited for planting with light-demanding species, such as black locust, honey locust, black walnut, and green ash.

CULTIVATION AND CARE.

Cultivation should be thorough and continued until the ground is quite fully shaded. When the trees begin to crowd, the plantation should be heavily thinned. The trees remaining should then be pruned to a height of 8 or 10 feet.

WHITE ASH (FRAXINUS AMERICANA).

FORM AND SIZE.

In the forest the white ash is a tall, slender tree with a smooth bole, which is surmounted by a small open crown of stout upright branches. The bole is often free from branches for more than half its length. In the open the trunk usually divides a few feet above the ground into several main branches, which form a graceful rounded head, rather open and widest near the base. On the bottom lands of the lower Ohio Valley, where the best development is attained, the white ash occasionally reaches a height of 100 feet, though in general it is a tree of medium size, with an average height of from 70 to 80 feet and a diameter of from 2 to 3 feet. The roots penetrate deeply into loose soil, but where hindered by rocks or an impenetrable substratum they develop an extensive lateral system.

RANGE.

The natural distribution of the white ash is from Nova Scotia and Newfoundland to northern Florida, central Alabama, and Mississippi, and westward to Ontario, northern Minnesota, eastern Nebraska, Kansas, Indian Territory, and Texas (Trinity River).

It seldom occurs in large masses, but usually as single individuals or in groups among other hardwoods. The associate species in-

clude many of the common hardwoods, such as the maples, elms, basswood, birches, walnut, and oaks.

The range for economic planting is from the valley of the Wabash and Ohio rivers north and west through Indiana and Illinois to the region of the Great Lakes; westward through Iowa, southern Minnesota, and eastern South Dakota; southward through eastern Nebraska and Kansas into northern Oklahoma and Indian Territory. The white ash will undoubtedly prove a valuable tree for planting in the arid regions on irrigated lands now being opened for settlement.

HABITS AND GROWTH.

The white ash prefers rich moist soil. The bottom lands of river valleys in the mild climate of the west central portions of its range produce the finest trees. A plantation will do best in a protected valley, on sandy loam that is light and easily worked. The white ash will thrive, however, in less favorable or even in adverse localities. A porous subsoil is essential, and a water table at a depth of 10 or 12 feet is of decided advantage. For general planting in the semiarid region of the Middle West the white ash is not so hardy and should yield preference to the small green ash.

Mature trees can endure only a moderate amount of shade, while young seedlings will start in dense shade, but require considerable light for their perfect development.

The rate of growth is rapid when compared to that of most of the associated hardwoods, but varies materially according to conditions of moisture and situation. In the southern part of its range post timber may be grown in ten or fifteen years. In a drier climate, where conditions are not so favorable, from fifteen to twenty years are required for the average tree to attain post size. On dry prairies the trunk is not more than 5 or 6 inches in diameter at twenty-five years. Trees grown in a dense stand in the Farlington plantation in Kansas made an average annual height growth of 1.7 feet and a diameter accretion of one-fifth inch annually This is very slow compared to the rate of growth of other trees under similar conditions.

White ash is attacked by a number of fungous parasites, which grow on the living leaves and do more or less injury. These parasites rarely appear in sufficient numbers to do very much harm to the tree affected. One specimen of fungus, which grows in the heartwood of the trunk and branches, changes the wood into a soft, pulpy, yellowish mass, unfit for lumber purposes. In regions

where this disease is common the ash never grows to be a very large or very old tree. In park or shade trees the disease may be prevented by coating wounds with an antiseptic substance such as coal tar.

White ash is also subject to insect injury. In case insects appear in numbers sufficient to do serious harm specimens should be sent to the Bureau of Entomology, where the insect will be identified and measures suggested for its control. Large trees are often doty at the base and sometimes have big heart cracks.

ECONOMIC USES.

The wood of the white ash is of great economic value. Wood from second-growth trees is usually more tough and elastic than that of the large, slowly grown first growth. Its most valuable qualities are strength and elasticity, and these combined with its ability to take a good polish and to season without injury make it a timber of first rank for furniture, car, and vehicle construction, interior woodwork, agricultural implements, and tools.

It is fairly durable in contact with the soil and is used for post timber. Because of its rapid growth, comparative freedom from disease, and ease of propagation white ash is certain to remain a favorite tree for ornamental planting. Where it thrives it is preferred to any other species of ash, but in regions of drought and extreme temperatures green ash should be selected in preference to white ash.

METHODS OF PROPAGATION.

Propagation is by seed, produced abundantly about once in three to five years, though individual trees along streams or in favorable open situations fruit more frequently. Natural reproduction is not abundant. The one-winged fruit ripens in October. It may be sown as soon as gathered or preserved for spring planting by stratifying in damp sand. If stratified, the seed should be mixed with about 3 parts of sand to 1 of seed and placed in a box in a cool cellar. Hand picking, although slow, is the most reliable method of collecting the seed, which can be gathered easiest from the low, open-grown, and most productive trees. Since the seeds of the several species of ash are similar in appearance, samples should be sent to the Seed Laboratory of the Department of Agriculture, where they will be identified and tested free.

Broadcast sowing of ash seed on prepared or unprepared ground, or planting in hills where the trees are to stand, is uncertain and

unsatisfactory; therefore nursery culture is advised. The nursery and seed beds may be prepared on any rich, well-worked soil, an old garden spot being an excellent place if the soil is not full of weed seeds. Planting may begin in the spring as soon as danger of frost is past. For convenience in weeding, it is recommended that the seed be sown in drills 8 to 12 inches apart for hand cultivation and 2 to 3 feet apart for a horse cultivator. Since the germination per cent is low, the seeds should be dropped so thickly that they will touch each other in the row. They should be covered about one-half inch deep and the soil rolled firmly or pressed down by a board. During germination moisture conditions should be kept uniform and irrigation or sprinkling resorted to in times of drought.

PLANTING.

The seedlings should attain a height of 6 to 12 inches the first season, and may be transplanted to the permanent site when 1 year old. The question of spacing depends on locality. For plantations in the Middle West a desirable spacing is 4 by 6 feet; in regions of more abundant rainfall the trees should be 6 feet apart each way.

The white ash is adapted to both pure and mixed planting. Species suitable for planting with this tree are black walnut, black cherry, hackberry, hardy catalpa, Scotch pine, and European larch.

CULTIVATION AND CARE.

Cultivation should be thorough and frequent enough to keep out weeds and grass. The plantation should be tilled for at least three years or until most of the ground is shaded. As soon as serious crowding begins, thinnings should be made so that the trees remaining may have ample space for development.

BLACK WALNUT (JUGLANS NIGRA).

FORM AND SIZE.

When grown in the open the black walnut is a rather symmetrical tree, with a massive crown, short trunk, and a form similar to that of open grown oaks and chestnuts. In the forest the trunk lengthens into a tall, tapering column, often with no limbs for a distance of 50 or 60 feet, and surmounted by a much reduced crown. The foliage is thin, and never completely shades the ground. On the lower mountain slopes of the Carolinas a height of 110 feet and a diameter of from 5 to 6 feet is often attained. The usual height of the mature forest-grown tree is from 70 to 90 feet, and the diameter from 30 to 45 inches. Trunks of low, spreading trees in the open often measure over 6 feet in diameter.

RANGE.

Black walnut is one of the most widely distributed and valuable of our deciduous trees. In nature it grows sparingly from southwestern New England westward, through New York, Ontario, Michigan, and Wisconsin, to southern Minnesota, thence southward, with central Nebraska and Kansas as the western limit, to south central Texas and Florida. It does not appear along the Gulf or the South Atlantic seaboard, and is much more abundant in the Central than in the Eastern States.

Although of fair size wherever found, black walnut attains its best development in the deep hollows of the western slope of the southern Alleghenies, on the rich bottom lands along the Mississippi and Ohio rivers, and in Arkansas, Missouri, eastern Nebraska, Kansas, and Indian Territory. In the mountains of the Carolinas and Tennessee it occurs in mixture with oaks and chestnut, while in the original hardwood forests in the river valleys of Ohio, Indiana, Illinois, and Kentucky it is found associated with the maples, hickories, oaks, basswood, cherry, and other hardwoods of the region, though not always intermingling closely with them. West of the Mississippi the walnut is confined to river valleys and moist situations. In this western region it is found associated with the coffeetree, green ash, hackberry, basswood, and white elm.

The walnut is nowhere a gregarious tree, but usually occurs in scattered groups or as isolated individuals among other species. Within the limits of its range there are regions where it is almost unknown, while within a few miles it may be common, though conditions in both localities seem identical.

The natural range has been increased both to the east and west by planting. In Rhode Island, eastern Massachusetts, and southern New Hampshire and Maine the tree was probably not native, but has been planted in small quantities for its nuts, and grows well. In Iowa and eastern Nebraska plantations of black walnut have been successfully made. Plantations have been made as far west as Salt Lake City, southern Idaho, and throughout California, with evident success. In California the black walnut has been planted to a very limited extent for timber, to a greater extent for ornament and the yield of nuts. In the San Joaquin and Sacramento valleys the California black walnut, native to the southern part of the State, has been grown successfully instead of the eastern black walnut.

HABITS AND GROWTH.

The ideal conditions for growth are found in the rich, moist, soil of bottom lands or on fertile hillsides which are protected from cold, sweeping winds. A calcareous soil or a sandy loam, containing a large quantity of humus, overlying a deep subsoil of gravel and a water table in which the long taproots can find a continual supply of moisture, furnishes the best conditions for growth. The surface soil should be moist, but not wet, and the subsoil porous.

While not especially adapted to widely varying conditions, the black walnut will grow in many localities outside of its natural range; but its form and rate of growth are appreciably affected by its environment. Throughout the entire Middle West south of the forty-fifth parallel, planting on limited areas may be attempted with fair prospects of success on all fertile prairie land, and especially in coves, valleys, and extensive bottom lands where the requisite moisture is present and partial protection from the wind can be had. This latter requirement may be secured by starting the plantation in the lee of a natural wind-break or by planting a shelter belt of hardy, rapid-growing species on the exposed sides. The most favorable range for economic planting is in the fertile valleys of the Ohio and Mississippi rivers and their tributaries, and on the bottom lands of the Carolinas, Georgia, Tennessee, Kentucky, Missouri, eastern Nebraska, Kansas, and Oklahoma. On upland soils, especially in the West, where there is a stiff subsoil, the species makes slow growth. In the southwestern plains the dry, hot weather of summer is often injurious, while in Minnesota and the Dakotas the cold of winter often kills back the season's shoots.

The black walnut is intolerant of shade. The foliage of a walnut

plantation is thin, seldom shading the ground to such an extent as to prevent the growth of grass and weeds.

In good soil the rate of growth is fairly rapid and is continued up to mature age. In the best situations planted trees occasionally make a diameter growth of nearly an inch each year, but under average conditions an increase of one-fourth to one-third inch is all that may be expected. A tree 12 to 15 years old will begin to bear fruit, and lumber will be produced in forty to sixty years. Along the northern limit of its range it is somewhat susceptible to sun scald, and should be protected from the wind and sun by hardier species.

Many tree defoliators and borers attack the walnut, but seldom do serious damage, since they are mostly of local distribution, and the damage done by them is limited in extent. In case insects cause serious damage, specimens, accompanied by a full description of their work, should be sent to the Bureau of Entomology of the United States Department of Agriculture for identification and suggestion as to methods of control.

ECONOMIC USES.

The wood of walnut is heavy, hard, strong, and of coarse texture. The sapwood is narrow and whitish in color and the heartwood is a chocolate brown, which deepens with age and exposure. The wood shrinks moderately in drying, and if care is taken dries without checking. It works and stands well, takes a good polish, and is valuable as a cabinet wood. It is very durable in contact with the soil, as only the sapwood decays.

Walnut was formerly much used for furniture and interior finish, especially in churches; in cabinetwork, for gunstocks, tool handles, and carriage hubs, and to some extent in the construction of ships. Formerly more abundant, it was used for fence posts and made into shingles. At present the market is much better in Europe than at home, and large amounts are exported in the form of logs, 10 to 20 feet long and 15 to 30 inches square. However, 30,000,000 feet B. M. of walnut were sawed in this country during the year 1905.

The price of walnut lumber is little, if at all, higher than it was twenty-five years ago; about $100 per thousand is paid for the best grades and $50 to $70 for medium grades. The average value of the lumber manufactured in 1900, as given by the last census, was $37 per thousand. Logs of unusually fine grain sometimes bring high prices for veneer manufacturing.

Walnut under favorable condition will reach post size in from ten to twelve years. However, timber of this size contains so large a percentage of sapwood that it is not first class for fence posts. If durable fence-post material is desired, the rotation should not be less than twenty-five years, and forty years would be more profitable, since the trees must have time to mature a considerable amount of heartwood.

The greatest returns will be realized from this species when it is planted with a view to growing saw timber. If a walnut plantation is established for this purpose, it is advisable to underplant with some tolerant tree that may be cut with profit in twenty or twenty-five years, leaving the walnut as the permanent stand until merchantable size is attained. As this will require a period of about seventy-five years, extensive walnut plantations are not advisable unless a long-time investment is sought.

METHODS OF PROPAGATION.

Under natural forest conditions the black walnut does not reproduce readily, and becomes almost extinct wherever lumbered clear. The tree does not reproduce by suckers and only sparingly from stump sprouts; squirrels usually destroy many of the fallen nuts and young trees are killed by dense shade.

The nuts may be stored over winter by stratifying them in moist sand or leaves in a sheltered place out of doors. In stratifying, 3-inch layers of sand should alternate with single layers of nuts. Boards should be placed around the edge of this store of nuts and the top protected against burrowing rodents. The sand should be kept moist, and the whole mass allowed to freeze.

For extensive and satisfactory propagation of the species, artificial planting is the only sure method. Because of the long taproots and consequent difficulty in transplanting, nursery culture is in general not advisable. It can, however, be made successful if root pruning is practiced and great care taken in moving the plants. Nursery culture, if attempted, should be conducted as follows:

The nuts should be planted at 6-inch intervals in nursery rows 3 feet apart, and covered 1 to 1½ inches deep. A preliminary freezing of the nuts will be beneficial rather than injurious. The plants in one year should attain a height of 12 to 14 inches, and may be transplanted to the permanent site in the spring when 1 year old.

PLANTING.

The plants may be set in furrows, or in holes dug with a spade care being taken to keep the roots from drying out, and to pack the earth firmly around them. In general the better plan is to omit nursery culture altogether and plant the nuts in their permanent place in the plantation. Either fall or spring planting may be practiced, but spring planting is usually best.

In the East a furrow or a series of holes the proper distance apart will be sufficient for the reception of the seeds. On the plains and prairies of the West, greater care in preparing the soil is essential. The sod should be broken, and the ground put in corn or some other common crop for one or two years. The nuts may then be planted in the spring in shallow furrows and covered with a plow to a depth of 2 or 3 inches and the ground well firmed down. The rows should be straight in at least one direction, to facilitate cultivation. The spacing will vary in different localities. An interval of 6 or 8 feet apart each way is recommended.

Since the black walnut is a long-lived, light-demanding tree, it may with advantage be combined in the plantation with a more heavily foliaged species. The associate trees should be allowed to grow until they clear the lower limbs from the walnut and stimulate it to a rapid upward growth, when they should be removed and the long-lived species left to finish its growth alone. Desirable trees for such a mixture are the hardy catalpa, hackberry, Osage orange, and boxelder. When the walnut and another species are thus combined, the walnut should be given two to three years' start in order that it may not be overtopped.

CULTIVATION AND CARE.

The plantation should be cultivated until the tops of the trees meet. During the first three years corn may be grown between the rows to give additional returns from the soil.

YELLOW POPLAR (LIRIODENDRON TULIPIFERA.)

FORM AND SIZE.

The mature, forest-grown yellow poplar, or tuliptree, has a long, straight, cylindrical bole, clear of branches for at least two-thirds of its length, surmounted by a short, open, irregular crown. When growing in the open the tree maintains a straight stem, but the crown extends almost to the ground and is of conical shape.

Yellow poplar ordinarily grows to a height of from 100 to 125 feet, with a diameter of from 3 to 6 feet and a clear length of about 70 feet. Trees have been found 190 feet tall and 10 feet in diameter.

RANGE.

Yellow poplar is distributed sparingly through southern New England and New York; it is more plentiful on the southern shore of Lake Erie and westward through northern Indiana and Illinois. It extends southward into Alabama and the other Gulf States as far as northern Florida. West of the Mississippi it is rare, except in northeastern Arkansas and southeastern Missouri. It is most abundant and of largest size in the south central part of its range, especially in Tennessee, Kentucky, and the western Carolinas, and in the basin of the Ohio River and its tributaries. It is characteristic of the distribution of yellow poplar that it is scattered by single trees or in groups throughout the forest, and is rarely the predominant tree except in the South, under especially favorable conditions. It is commonly associated with chestnut, the oaks, walnuts, hickories, maples, black cherry, locust, and beech; and is occasionally found with hemlock and white pine.

The tree is hardy east of the Mississippi, except in the colder portions of the Northern States; and, on suitable soils, may be planted throughout its range.

HABITS AND GROWTH.

Yellow poplar is very exacting in soil and moisture requirements. It demands deep, fertile, well-drained soil and a constant and even supply of soil moisture. The tree grows best on moist loam or rich sandy soil in which is mixed a considerable quantity of humus. It does not thrive on heavy clay or dry ridge soils, and can not grow in standing water. In its early life it requires a fresh, porous, upper soil. The largest specimens are found in protected coves along

water courses and on the northern and eastern slopes of ravines and valleys.

The tree is very intolerant and prunes itself well with even moderate side shade. While the seedlings can endure considerable shade, the trees demand more light as they grow older, and at maturity are nearly always taller than their associates, with their crowns fully exposed.

In early life the growth is principally in height, and the development of one continuous main stem is characteristic throughout. The growth is rapid and the tree often lives more than three hundred years; during the first forty or fifty years the height growth is from 1 to 2 feet annually, and the average diameter growth from one-tenth to one-fourth inch. After fifty years the rate of growth gradually decreases.

Yellow poplar is very susceptible to injury by fire. Old trees are often hollow-butted as the result of repeated burning about the base. Near the western limits of its range the tree is sometimes injured by sun scald.

Injuries by insects should be reported to the Bureau of Entomology, United States Department of Agriculture.

ECONOMIC USES.

The wood is usually light, but varies in weight; it is soft, tough, but not strong, and of fine texture. It is fairly durable when exposed to the weather or in contact with the ground. It shrinks slightly and seasons without injury, and works and stands exceedingly well. The sapwood is thin, light in color, and decays rapidly. The wood is used for siding, paneling, and interior finishing, and in the manufacture of toys, boxes, culinary woodenware, wagon boxes, carriage bodies, slack staves and heading, and backing for veneer. It is in great demand throughout the vehicle and implement trade, and also makes a fair grade of wood pulp.

With the diminution of the white-pine supply yellow poplar is much used in its place. The lumbermen recognize two kinds of poplar timber, white and yellow. The difference in color is caused mainly by the difference in site conditions, since trees grown on dry, gravelly soil produce a wood that is lighter in color and harder to work, and is called "white poplar" or "hickory poplar." The "yellow poplar" is grown on rich alluvial or limestone soil, and has a rich yellow heartwood which is highly prized because of its fine grain and easy working qualities.

Yellow poplar is an excellent tree for shade and ornament, and is especially suited to these purposes in cities where bituminous coal is burned. Forest planting of this species for economic purposes has never been attempted, but it should prove profitable wherever natural conditions are favorable, because of the rapid growth of the tree, its large size and splendid form at maturity, and the value of the wood.

METHODS OF PROPAGATION.

Yellow poplar reproduces itself almost entirely by seed. Its ability to sprout from the stump is very limited, and can not be depended upon.

Seeds are produced abundantly nearly every year, though only from 5 to 10 per cent are fertile. They are borne in a cone-like fruit 1 to 2 inches long. Young trees are likely to produce seed which is absolutely worthless, and on older trees good seed is found only in the centers of the cones on the highest limbs. Seed should be collected in the fall when mature, and may be sown at once or stratified in sand for spring planting. It is advisable to plant in the fall; germination will then take place the following spring. If sown in the spring the seeds have a tendency to lie in the ground a year before germinating.

The use of nursery-grown seedlings or transplants is recommended for establishing plantations of yellow poplar. Sowing in the permanent site, however, is occasionally successful.

To grow nursery stock the seed should be sown thickly in drills, in light, rich, sandy soil and covered to a depth of one-half inch. It is especially important that the soil be kept evenly moist. More water should be supplied during the germinating period than later. It may be found necessary to provide partial protection on hot, sunny days during the first season, especially in the South. Seedlings may grow in the nursery for one or two years, but should not remain longer, because of the strongly developed taproot and few lateral roots, which make transplanting difficult. Transplanting 1-year-old seedlings into nursery rows will stimulate the development of fibrous roots and insure vigorous plants, but this operation is not generally advisable, because of the added expense. If seedlings are left for more than one year in the seedbed they should be cut back to the ground before being moved. Vigorous sprouts will then replace the stems.

PLANTING.

Seedlings reach suitable planting size in one year, and should be transferred to the field very early in the spring, before the buds start. They should be spaced 6 feet apart each way. No preparation of the whole site prior to planting is needed, except where there is a tough sod. In this case the ground must be broken and the grass turned under if possible; otherwise the sod should be removed from a small area where a tree is to be placed.

Yellow poplar is not well adapted for planting in pure stands, but should be mixed with other decidous species. Unless the other trees in the mixture are slow-growing it must be given a start, so that it will not be overtopped. If the plantation is in a sheltered valley or rich bottomland, yellow poplar may be planted as the predominant tree of the mixture. In more exposed situations the species with which it is planted should be in excess, to provide protection from high winds and frost.

Any moderately shade-enduring hardwood may be planted with yellow poplar, or mixture with white pine and Norway spruce should also prove suitable.

CULTIVATION AND CARE.

Yellow poplar will rarely be planted on tillable land, so that cultivation in most cases will be impossible. Ordinarily young trees will not be choked out by grass or weeds because of their rapid growth. When field sowing of the seed is practiced, however, it may be necessary to check the weeds for the first two or three years.

No grazing should be allowed in the plantation and fires should be absolutely kept out, since the yellow poplar, even when mature, is very easily injured by fire.

Quantity and Character of Creosote in Well-Preserved Timbers

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INTRODUCTION.

The practice of preserving timber by impregnating it with antiseptics is spreading rapidly in the United States. Engineers and business men are recognizing more and more fully that, largely because of the increasing scarcity of good timber and its higher price, timber preservation is a paying investment.

Of the various preservative processes which have been devised, those using coal-tar creosote have proved the most efficient. In the long run they are also frequently the most economical, the longer service offsetting the greater first cost as compared with processes using metallic salts. Moreover, creosoted wood can be used for some purposes, as for piles set in salt water, for which wood treated with metallic salts is but slightly more durable than untreated timber.

Recent reports on the service of creosoted railroad cross-ties, and of piles placed in salt water, have clearly shown that, while proper treatment gives remarkably good results, much of this timber was not properly treated and has not lasted as it should. On the other hand there is abundant evidence that the growing use of creosote, and the fact that creosoting means the investment of considerable capital in the expectation of a good return through the increased life of the timber, makes it imperative that we should know, as completely as possible, just what constitutes efficient creosote treatment.

The efficiency of treatment will depend on three things—the amount of creosote, its character, and the thoroughness with which the timber is penetrated. The proper amount of creosote will depend upon the intended use of the timber. Piles, for instance, which must resist the attacks of marine borers, need more creosote than telephone poles; and piles in warm waters require more than those in cooler waters. The sort of creosote best suited to prevent decay and the inroads of marine borers can be ascertained only by

many careful experiments. The proper means for securing a maximum penetration is an engineering problem, complicated by many factors, such as the differences of wood structure or the moisture content of the timber.

There are many ways of approaching this problem. One of the most promising is a study of the nature of the creosotes present in timbers which have given long service. The results of a series of analyses of the oils present in such timbers forms the most important part of this paper. A brief account of the source and composition of coal-tar creosote precedes the description and discussion of the experiments.

MANUFACTURE AND COMPOSITION OF CREOSOTE.

SOURCE AND COMPOSITION OF COAL TAR.

When certain varieties of coal are heated in an oven or retort, in the absence of sufficient air for their combustion, the coal is decomposed and gas, tar, and coke are formed. The gas and tar rise from the heated mass and the coke remains in the retort. Coke and illuminating gas are manufactured in this way. Where coke is the main product the "beehive" oven is used and the gas and tar are not collected, but when the volatile materials are to be collected the "by-product" oven is used. In making illuminating gas the coke and tar are regarded as by-products, and one of the problems of management is how to dispose of these by-products advantageously.

Coal tar is an extremely complex mixture of organic compounds of which the composition is by no means constant, but varies not only with different coals but also with different treatments of the same coal. The same coal will yield at the same plant various qualities of coke, gas, and tar, depending on the amount of heat applied, the quantity of air admitted, and the season of the year. When a low heat is applied a relatively small amount of gas and tar is evolved and the tar contains large quantities of compounds belonging to the paraffin series. On the other hand, with a high temperature much larger amounts of gas and tar are obtained and the predominant compounds of the tar, in nearly all cases, are those belonging to the aromatic series, such as benzene, toluene, phenol, naphthalene, anthracene, etc.

THE PRODUCTION OF CREOSOTE FROM COAL TAR.

The first distillation of crude tar, in which several separate fractions are usually taken, is made in large iron retorts holding from 10 to 30 tons. The forms of the retorts and the manner of con-

trolling the distillation vary more or less in different works. In some cases the still is provided with a thermometer inclosed in an iron tube screwed into the still head; in other cases the time for changing the receiver for various fractions is judged solely by the specific gravity and other properties of the distillates. The separation aimed at is more or less accurately attained in both ways.

In Germany the fractions are frequently taken as follows: The temperature is that registered by the thermometer in the tar at the beginning of the distillation, but free from the oil and indicating the temperature of the vapor passing over when anthracene oil begins to distill.

First light runnings up to	110° C.
Light oils	110° to 210° C.
Carbolic oils	210° to 240° C.
Heavy or creosote oils	240° to 270° C.
Anthracene oils	270° to 400° C.

At many English works the following fractions are taken with the thermometer placed as in the German procedure just cited:

Light naphtha up to	110° C.
Light oil	110° to 170° C.
Carbolic oils	170° to 225° C.
Creosote oils	225° to 270° C.
Anthracene oils	270° to 360° C.

These temperatures are by no means universally accepted in the respective countries, and one or more fractions are often omitted; when, for example, it does not pay to extract carbolic acid, or when the demand for anthracene is limited.

Owing to the variable constitution of the tar and to the different temperatures between which fractions are taken, the products of this preliminary separation are frequently widely different in physical character and chemical composition.

In distilling according to the German method given above, the "first runnings" and "light oils" contain, among other things, benzene, toluene, and the xylenes; the "carbolic oils" contain phenol, the cresols, and some naphthalene; the "creosote oils," small quantities of phenols, naphthalene, anthracene, and many other hydrocarbons; the "anthracene oils," anthracene, acridene, etc. The residue in the still is either soft or hard pitch, according to the point at which the distillation is stopped. When the anthracene oil is completely distilled the residue is largely hard pitch or carbon, and this is used as a briquette binder and in the manufacture of electric light carbons. When the distillation is stopped at

an earlier stage soft pitch is obtained which contains a considerable quantity of the high-boiling tar constituents, and is used for roofing and for builders' papers.

At present there is almost no market in America for hard pitch, whereas the demand for roofing pitch is very great. This demand for soft pitch, together with the lack of an American market for anthracene, explains why the distillation of tars is not carried so far here as it is at some of the foreign works.

STATISTICS OF THE PRODUCTION AND IMPORTATION OF CREOSOTE.

In 1898 there were produced at gas works in the United States 24,384,798 gallons of coal tar, valued at $902,400, or 3.7 cents per gallon. In the same year about 4,023,000 gallons of coal tar were produced by 520 "by-product" coke ovens, the total product for the year being 28,407,798 gallons.*

In 1903 the total amount of tar produced amounted to 62,964,393 gallons, valued at $2,199,969, or 3.49 cents per gallon. This includes the tar produced at 1,956 "by-product" coke ovens. There are no reliable figures showing what part of this total was produced at these "by-product" ovens, but the amount of coal coked at such ovens in that year was 2,605,453 tons.* The average yield of tar per ton of coal for the year 1903 was a little over 10 gallons.* The averages for the gas works and by-product ovens, separately, however, differ from the general average, the former for that year being about 12.5 gallons per ton and the latter about 8.5 gallons. Therefore it follows that approximately 22,150,000 gallons of coal tar were produced at "by-product" coke ovens in the United States in 1903. This leaves approximately 40,800,000 gallons as the production of gas works for this year.

In 1904 the total production of coal tar amounted to 69,498,085 gallons, valued at $2,114,421, or 3.04 cents per gallon. Of this amount 27,771,115 gallons were produced in "by-product" coke ovens and 41,726,970 gallons at gas works.*

In 1905 the total amount of tar produced was 18,022,043 gallons, valued at $2,176,944, or 2.73 cents per gallon. Of this amount, 36,379,854 gallons were produced in by-product coke ovens and 43,642,189 gallons at gas works, so that the output of by-product coke ovens increased considerably over that of the previous year, while the output of the gas works remained nearly stationary.*

No reliable figures are obtainable showing how much coal tar is distilled in this country. Practically all of the by-product tar is

*Annual Reports, U S. Geological Survey

distilled and approximately one-half of the total tar made at gas works. It is safe to say that at least 40,000,000 gallons of tar were distilled in the United States in 1903. If, then, we assume that the average coal tar produced in this country contains at least 10 per cent of oils which can be used as, or added to, creosote oil, it follows that the production of creosote oil in the United States in 1903 was approximately 4,000,000 gallons.

Making similar estimates from the statistics of the production of coal tar in 1904 and 1905, it is safe to say that at least 4,850,000 gallons of creosote oil were produced in this country in 1904 and at least 5,800,000 gallons in 1905.

In 1903, 3,711,565 gallons of creosote oil, valued at 5.8 cents per gallon, were imported into this country. In 1904 the importation amounted to 3,783,472 gallons, valued at 6.3 cents per gallon. In 1905 it was 7,750,531 gallons, valued at 5.4 cents per gallon.*

It would therefore appear that about 7,700,000 gallons of creosote oil were used in this country in 1903 for the impregnation of timber, that in 1904 the amount used was approximately 8,650,000 gallons, and that in 1905 approximately 13,550,000 gallons were used.

COMPOSITION OF COMMERCIAL CREOSOTE.

Technically speaking, the fraction of oil passing over between 240° C. and 270° C. during the first distillation of the crude coal tar is known as "creosote oil," "heavy oil," or "dead oil of coal tar." In practice, however, the oily residues which remain after extracting carbolic acid, napthalene, and anthracene from the various distillates in which they occur are added to the creosote oil, and, in consequence, many of the creosote oils of commerce contain considerable amounts of materials having boiling points higher than 270° C. and lower than 240° C. As a matter of fact, it is the practice at nearly all distilling plants to add to the "creosote well" or tank all those oils and residues which can not profitably be worked over and used to greater commercial advantage.

The solvents which are used in the purification of napthalene and of anthracene are sometimes added to the "creosote well," and this accounts for the occasional presence of paraffin oil in creosote.

The "creosote well" or tank is usually constructed of steel plate, and is fitted with inclosed steam coils at the bottom, in order that the solid materials crystallizing out can be melted before the oil is delivered to tank cars, tank steamers, or barrels. A stirring device is also frequently made use of to secure uniformity in the quality

* Annual Reports of Commerce and Navigation for 1904 and 1905, Department of Commerce and Labor

of the supply obtained from any one storage tank from which frequent deliveries are made.

The creosote oil of commerce contains phenol (carbolic acid), the ortho, meta, and para cresols, naphthalene, the *a* and *B* methylnaphthalenes (the former being a liquid, the latter a solid melting at 33° C.), anthracene, phenanthrene, acridene, and small quantities of certain high-boiling bases and acids. When first distilled, creosote has a distinctly fluorescent appearance, and is light green in color. There is strong evidence for the belief that some of the individual constituents in creosote oil combine with each other and probably form new products.

At certain works carbolic acid is extracted, and the creosote oil coming from such places is low in "tar acids;" at other places, naphthalene is of considerable commercial importance, and the creosote oils obtained from these works contain little naphthalene. Usually anthracene separates with naphthalene, and in the event that the latter is frozen out, the former is also lacking in the oil which is placed on the market. In America the creosote oils usually contain large amounts of naphthalene, very small amounts (about 5 per cent) of phenols or cresols, and practically no anthracene. Little anthracene oil is found in the average specimen of creosote oil made in the United States for the reason already mentioned, namely, that in forcing the distillate to a temperature at which anthracene oil passes over, the soft pitch is ruined for roofing purposes, and a hard pitch, which is of practically no commercial importance in this country, is obtained.*

It is evident that these variations in manufacture result in creosotes differing greatly in physical and chemical properties. Some commercial creosotes are rather thin oils, some are almost entirely solid with naphthalene, and some are heavy oils with a large proportion of high-boiling constituents.

The different sorts of oils are believed to have different preservative values when injected into timber, but there is, unfortunately, a lack of uniformity in opinion. Some investigators have advocated oils rich in phenols, some those containing much naphthalene, some those containing a maximum of the high-boiling compounds. But little has been published on the subject.

* For a more extended discussion, see Lunge's Coal Tar and Ammonia.

ANALYSES OF THE CREOSOTE EXTRACTED FROM TIMBER WELL PRESERVED AFTER LONG SERVICE.

To determine what is, in fact, a good oil, a natural way is to examine the composition of those oils which have protected treated timber satisfactorily. This can be done by extracting and analyzing the oils from timbers the exact history of whose service is known.

The writer secured from various sources a number of creosoted timbers which had been in varied and extended use under markedly different climatic conditions. The method of extracting and analyzing the oils from these timbers is given below.

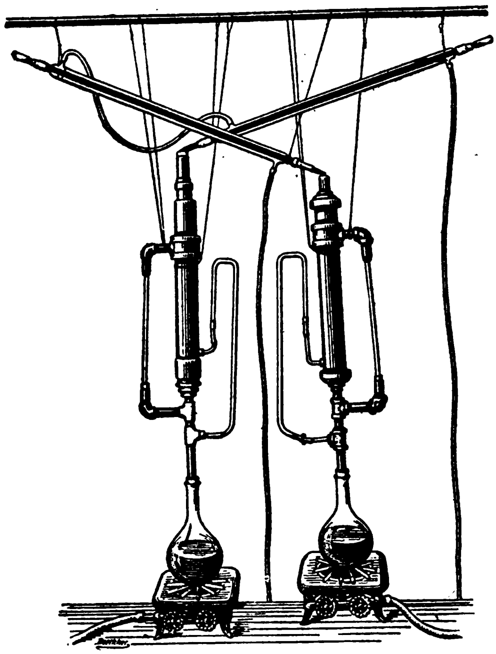

FIG. 1.—Apparatus for extracting creosote from wood cuttings.

METHOD OF EXTRACTING CREOSOTE FROM TIMBER.

As soon as a specimen of creosoted wood was received it was placed in a turning lathe, and cuts about 0.02 inch in thickness were made with a sharp tool, the lathe running slow enough to prevent the generation of such heat as experience showed would volatilize the oil. If the specimen was too small for the lathe, borings were made with a 1-inch auger. In every case, however, the

volume of wood worked up into a fine condition for extraction was accurately determined.

The cuttings or borings were then placed in large extractors (fig. 1), and extracted with absolute alcohol, and subsequently with anhydrous benzene. To prevent the iron of the extractors from combining with the tar acids, their interior was heavily lined with pure tin, a metal which experiment showed to be unaffected by tar acids. When the extraction was complete, the extract was filtered and the alcohol and benzene were distilled off in turn. In this removal of the solvents, use was made of a large Hempel column filled with glass beads, or of a Le Bel and Henninger tube. It was found that when these aids to fractionation were not used napthalene would volatilize with the vapors of alcohol and benzene.

The only troublesome materials which this extraction could remove from the wood, and so contaminate the creosote, were the eleo-resins. Although it is possible to separate these compounds from creosote, this involves more error than disregarding them entirely.

The amount of oil obtained from each specimen is stated in terms of anhydrous creosote per cubic foot of timber. The actual cubic content of each specimen analyzed was accurately determined, and this, together with the weight of creosote oil obtained from it, formed the only basis of the calculations employed. The result of the estimation of the content of creosote was confirmed in every case by an analysis made in the ordinary glass Soxhlet extraction apparatus. The results obtained with the two sets of apparatus agreed to within less than one-half pound to the cubic foot. The results given in the table on pages 14 to 16 are the average of the two determinations.

METHOD OF ANALYZING THE EXTRACTED CREOSOTE.

The analytical tests commonly believed to give the most information concerning creosote were applied to the extracted oils. A fractional distillation is the most important of these tests. The extracted creosotes were therefore fractioned, and when the precipitates of solid napthalene and of anthracene oil* were noticeably large the amounts of these deposits were determined. The percentage by volume of tar acids was also estimated. The specific gravity was not determined, since a very slight admixture of resin causes a marked change in specific gravity.

* Anthracene oil is here used in the commercial sense; its oil contains other solids besides anthracene.

FRACTIONAL DISTILLATION.

Of the different methods used in analyzing the extracted oils, the one selected, after a series of preliminary tests, appeared best suited for the work in hand.

Figure 2 shows the apparatus used in making fractional distillations.

The distilling vessel was the side-neck flask of Jena glass. The outlet tubes of the flasks used were placed rather below the middle of the neck, and, to insure a good condensation and prevent the ignition of the first part of the distillate, these delivery tubes were 40 cm. long. Retorts were not used because the fractions obtained from these vessels are much less sharply defined. In place of the

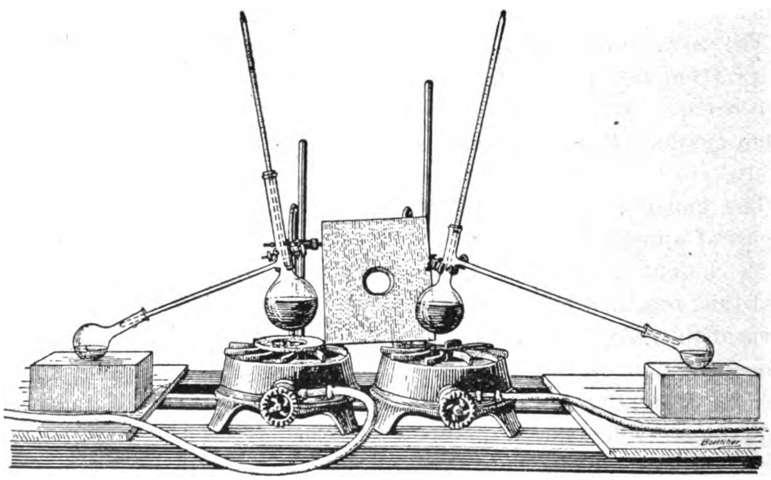

FIG. 2.—Apparatus used in making fractional distillations.

usual Bunsen burner, a Rogers burner was employed, as the flame is under better control and the contents of the distilling flask less likely to bump or froth. During distillation the flask was placed on a thick asbestos board through which a hole about 1½ inches in diameter had been cut. This asbestos sheet prevented the radiation of heat from the burner to the thermometer. A mica shield was placed around the distilling bulb whenever protection from draft was necessary.

The thermometers used were made of Jena normal glass and filled with nitrogen. To guarantee their accuracy, they were carefully compared with a set of Anschütz standard thermometers. They were always so placed that their bulbs were just below the

outlet tube, so that the temperature recorded at any moment was that of the vapors passing over.

Two hundred and fifty grams of oil were used for each distillation. The fractions were caught in small flasks which had been previously cleaned, dried, and weighed. The amount of each distillate was determined by a second weighing taken after the fraction had cooled.

When a complex mixture such as creosote is distilled the various distillates passing over do not volatilize at the exact boiling point of the individual compounds which they contain, and the compounds can not be separated in the pure state except by repeated distillations. If all creosote oils were similarly constituted, then, by means of a series of analyses, it could readily be determined at what temperatures the various constituents volatilize; but since oils vary greatly in composition, this is not possible; such temperatures as are determined upon for the separation of the various fractions are, in a measure, arbitrary. For instance, if an oil is rich in naphthalene and also contains a certain amount of material distilling below 200° C., some of the naphthalene is liable to volatilize with the lighter oil, and it will have entirely passed over when a temperature of 245° C. is reached. On the other hand, if the oil contains a large amount of the higher-boiling constituents, such as anthracene, and also a considerable amount of naphthalene, the latter is frequently not gotten rid of before a temperature of 250° C. is reached. The point at which naphthalene ceases to come off, if it is present, can be determined by allowing a drop of the distillate supposed to contain it to fall on a piece of cold porcelain. If the drop solidifies, the presence of naphthalene is shown.

In over 800 distillations conducted by the writer it was found that 92 per cent. of those oils which contained naphthalene gave it off between 205° C. and 245° C., and one of the fractions has consequently been taken between these temperatures.

After conducting tests on a great many oils the writer was of the opinion that the most information could be obtained by separating the distillates as follows:

1. To 170° C.
2. 170° C. to 205° C.
3. 205° C. to 245° C.
4. 245° C. to 270° C.
5. 270° C. to 320° C.
6. 320° C. to 420° C.
7. Residue above 420° C.

Fraction No. 1 contains the light oil and water. In case much water is present some of the naphthalene will frequently volatilize with it.

No. 2 should contain phenol and the cresols.

No. 3 contains naphthalene and the two methylnaphthalenes; these bodies crystallize out, and by filtration the amount of solid naphthalene can be determined.

No. 4 contains, among other compounds, dimethylnaphthalenes.

No. 5 was usually entirely liquid on cooling, an dits composition is complex and variable. In case little anthracene oil is present, some of it will be found in this distillate.

No. 6 usually contains anthracene oil, phenanthrene, acridene, etc., and solidifies on cooling.

the residue above 420° C. may contain practically the same as No. 6, and also tar.

DETERMINATION OF TAR ACIDS.

"Tar acids" is a technical term used to denote all those creosote constituents which contain hydroxyl groups. The known compounds of this sort occurring in creosote are phenol or carbolic acid; the ortho, meta, and para cresols, usually termed cresylic acids; a and β naphthol, and the xylenols.

The method of estimating the tar acids is based on the following reactions: When a phenol—as, for example, carbolic acid—is treated with sodium hydroxide solution, the water-soluble sodium phenolate is formed, thus:

$$C_6H_5OH+NaOH=C_6H_5ONa+H_2O.$$

On treating this sodium phenolate with a mineral acid the salt is broken up and the original phenol recovered, thus:

$$2C_6H_5ONa+H_2SO_4=2C_6H_5OH+Na_2SO_4.$$

In using these reactions to estimate tar acids in creosote it is convenient to distill 100 cm³ of oil until a temperature of 420° C. is reached, collecting the distillate in one vessel. This oil is extracted with 40 cm³ of sodium hydroxide solution of 1.15 specific gravity, the mixture being warmed and frequently shaken. The oil and the aqueous solution are separated in a separatory funnel, and a second and third extraction made, using 30 and 20 cm³, respectively, of the sodium hydroxide solution. The three alkaline extracts are united in a 200 cm³ graduated cylinder, and the solution is acidified with dilute sulphuric acid. The mixture is then allowed to cool and the volume of tar acids noted.

RESULTS OF THE ANALYSES.

The results of the analyses of the creosote extracted from 37 different samples of wood are given in the Appendix. The majority of these samples were obtained from various English companies using cresoted wood. Such details as could be learned concerning the history of the timbers are given in the footnotes.

A clearer comprehension of the analytical results may be had by dividing the timbers into several classes and comparing the average figures in the various groups. The 37 samples may be divided into six classes: Railroad ties, including eighteen English samples and one American sample; English piles; American piles; paving blocks showing good service, two English and two American; one sample of American paving block showing poor service, and one conduit pipe. The average results in each of these groups and the general average of all the well-preserved timbers are given in the table below:

Analyses of extracted oils.

Samples.	Average service.	Creosote to the cubic foot	Distillation of extracted oil.								
			To 205°.	205° to 245°.	245° to 270°.	270° to 320°.	320° to 420°.	Residue above 420°.	Solid naphthalene from distillates.	Solid anthracene oil from distillates.	Tar acids.
	Years.	*Pounds.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cm³.*
19 cross ties....	21.84	9.58	0.025	12.07	13.88	23.80	24.69	25.27	1.19	23.47	0.65
6 English piles.	43.00	9.19	.46	16.92	15.31	21.06	22.77	23.04	....	19.95	.61
6 American piles......	20.20	15.64	.57	30.28	15.82	18.49	13.21	21.43	25.93	43.27	....
4 paving blocks	23.60	15.70	.29	21.34	21.39	18.73	19.40	18.64	12.52	40.40	.52
1 paving block, poor service..	9.00	5.77	9.62	14.41	19.27	41.74	11.23	3.40	....	....	....
1 conduit pipe..	14.00	8.74	5.08	27.23	10.46	27.68	19.03	9.93	23.17	14.28	....
Average of 36 timbers giving good service.........	24.90	11.18	.36	17.37	15.18	22.00	21.71	23.09	6.98	27.81	.50

DISCUSSION OF THE ANALYTICAL RESULTS.

QUALITY OF OIL FOUND.

The average figures show that the quantity of creosote in these long-service timbers was not excessive. It is an unfortunate circumstance that we know practically nothing of the amount of oil which was injected into the various samples. Six of the ties, Nos.

8, 9, 104, 106, 109, and 113, were said to have received 2½ (English) gallons of creosote each. Assuming that the creosote had a specific gravity of 1.05, and that the ties contained at least 2½ cubic feet of wood, it would appear that these timbers received 10.50 pounds of oil to the cubic foot. The average amount present was 8.56 pounds.

The American piles show a much higher content of oil than the English samples. It should be noted that the American piles were all set in warm water, those farthest north being on the Virginia coast.

There is a considerable contrast between the quantity of oil present in the paving blocks which gave good service and the sample which was short lived. It is impossible to say which was the more important factor in determining this difference in service—the quantity or the quality of the injected creosote. Very likely it was a combination of both factors.

In general the results tend to show that 10 pounds of creosote per cubic foot is ample for railroad ties, and that piles require from 10 to 20 pounds, according to the location in which they are to be placed. If a creosote contains much light oil, a proportionately larger quantity must be used.

CHARACTER OF THE EXTRACTED CREOSOTE.

A difficulty in the proper interpretation of the results of the analyses arises from our ignorance of the quality of the oil used in treating the various timbers. It is, therefore, possible to believe that the materials which have volatilized from the timbers have created an antiseptic environment which has been a most important factor in preserving the wood.

Notwithstanding this legitimate query concerning the possible efficacy of the substances which has disappeared, the analyses furnish a strong argument in favor of the use of heavy oils. Tie No. 112, for example, had seen but fourteen years' service, two-thirds the average of the ties, and doubtless would not have suffered decay for many years to come, yet it does not contain more light oil than the average of the tie group, but, on the contrary, the creosote from this specimen was over half recovered as solid anthracene oil. If the constituents present in the timbers represented a nonefficient residue from which the effective light oils had evaporated, we should expect to find a relatively high proportion of light oils in this tie which had seen a shorter term of service. The natural interpretation of the results is that it is the heavy, high-boiling com-

pounds which stay in timber and are an efficient barrier to the entrance of water and to the attacks of fungi and borers.

The creosotes recovered contained practically nothing which boiled below 205° C. The general average shows that 32.9 per cent. of the oils distilled below 270° C. and 66.95 per cent. above—that is, two-thirds above and one-third below this rather high temperature. Another noticeable fact is the large amount of solid anthracene oil recovered from the distillates of many samples, the highest being 57 per cent.

A distinctive feature of the creosotes from American piles was the quantity of naphthalene which they contained. The average from this class of timbers was nearly 26 per cent., and one sample showed over 48 per cent. It appears probable that the creosotes used in treating these timbers contained much more naphthalene than the oils applied to the English piles. The results indicate that this substance possesses value for timber treatment, although it probably is inferior to anthracene oil. It is worth noting that these long-lived American piles contained more anthracene oil than naphthalene.

Perhaps the most striking thing is the disappearance of the tar acids. It is certainly conservative to place the original tar-acid content at 5 per cent. Yet the extracted oils showed but a tenth of this amount. It is possible that these compounds, on account of their hydroxyl groups, have undergone chemical changes during the many years that they have been exposed to varying amounts of water and air, to the reactive lignin portion of the wood, and to the numerous compounds present in creosote. On the other hand, these phenol bodies may have volatilized or been washed from the timbers.

It appears, therefore, that light oils, boiling below 205° C., will not remain in timber, but that heavy oils, containing a high percentage of anthracene oil, will remain almost indefinitely and protect the wood from decay and boring animals. It is probable that naphthalene stays in wood for many years, but whether it is as valuable as anthracene oil is open to question. The value of the tar acids has apparently been overestimated by many persons, for although it has not been proved that they are valueless, they have been shown to possess poor staying qualities.

APPENDIX.

RESULTS OF ANALYSES.

Analyses of extracted oils.

Sample.	Source.	Species.	Service.	Creosote per cubic foot.	Distillation of extracted oil. To 205°.	205° to 245°.	245° to 270°.	270° to 320°.	320° to 420°.	Residue above 420°.	Total.	Solid naphthalene from distillates.	Solid anthracene oil from distillates.	Tar acids.
			Years.	*Pounds.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cm³.*
Tie No. 106	Glasgow and Southwestern Ry., Scotland	Pine	16	4.06	......	16.32	13.24	20.15	24.10	25.93	99.74	......	......	0.51
Tie No. 104	do.	do.	18	9.24	......	9.37	18.17	27.54	21.38	23.01	99.47	......	......	.36
Tie No. 113	do.	do.	18	8.01	......	9.75	18.54	24.96	22.42	24.07	99.74	......	......	1.13
Tie No. 109	do.	do.	16	8.29	......	7.08	12.45	16.68	40.84	22.52	99.57	......	......	.74
Pile No. 118	Great Western Ry., Heath Division, England	Yellow pine	47	7.68	......	19.92	17.58	20.62	14.48	27.11	99.71	......	32.15	.78
Tie No. 107	do.	Baltic redwood	42	12.71	......	9.45	12.30	27.56	33.48	17.87	100.66	......	51.07	.96
Tie No. 105	do.	do.	a33	5.08	......	6.83	10.16	26.11	32.17	23.91	99.18	......	......	......
Tie No. 103	London and Northwestern Ry. Co., England	do.	19	14.07	......	17.78	11.88	21.26	14.64	34.01	99.57	......	35.14	.26
Tie No. 110	do.	do.	19	13.84	......	18.23	16.61	23.01	12.78	29.11	90.78	......	26.87	.68
Paving blocks Nos. 88 and 89	Northeastern Ry. Co., England	Yellow pine	20	17.19	......	20.13	10.27	12.18	27.46	29.78	99.82	21.46	57.03	1.19
Tie No. 114	do.	Pine	30	7.41	......	15.44	7.44	15.68	44.96	16.14	99.66	......	......	.37
Paving blocks Nos. 90 and 91	City Engineer, Hull Corporation, Hull, England	Yellow pine	11	14.37	......	21.03	24.45	7.68	25.06	21.78	100.00	24.93	......	.87
Tie No. 108	Maryport and Carlisle Ry. Co., England	......	23	5.17	......	10.59	12.61	28.56	20.32	27.87	99.95	......	......	.62
Tie No. 2	Highland Ry. Co	Scotch fir	20	5.93	......	15.78	8.04	27.80	18.12	29.81	99.55	......	48.14	.76
Tie No. 3	do.	do.	20	9.03	......	10.15	16.32	20.54	12.63	40.02	99.66	......	52.13	.54
Tie No. 41	do.	do.	22	12.76	......	10.46	20.34	22.63	16.32	29.83	99.58	......	......	1.14
Tie No. 101	North British Ry. Co., Scotland	do.	24	11.46	......	8.32	26.36	23.42	29.58	11.86	99.54	......	40.15	.38
Tie No. 102	do.	do.	21	8.19	......	18.24	12.16	28.92	22.76	17.35	99.43	......	......	.21
Tie No. 112	do.	do.	14	7.21	0.47	7.65	8.03	17.58	38.88	27.97	100.58	......	53.04	1.23
Pile No. 116	Clyde Navigation Trust, Glasgow	Red pine	46	8.42	......	9.44	16.92	29.68	32.08	11.03	99.15	......	......	......
Pile No. 111	do.	do.	46	8.07	2.76	19.53	14.61	18.15	17.23	27.03	99.31	......	......	......
Pile No. 117	do.	do.	46	9.31	......	22.20	20.10	24.30	16.24	16.84	99.68	......	33.14	......
Pile No. 4	do.	do.	46	12.61	......	16.87	12.15	13.25	25.37	32.30	99.94	......	54.42	1.07

Pile No. 5	...do	Pitch pine	21	9.06	....	13.56	10.52	20.34	31.24	23.92	99.58	....	....	1.78
Tie No. 8	...do	...do	22	12.36	....	9.03	15.21	29.46	13.35	32.91	99.96	....	41.16	1.37
Tie No. 9	...do	Baltic redwood	16	9.42	....	6.39	10.38	27.75	31.86	23.51	99.89	....	52.14	1.15
Pile No. 81	Norfolk Creosoting Co.	Loblolly pine	11	18.34	....	38.88	13.76	13.12	10.08	24.02	99.86	34.47	37.24	....
Pile No. 82	...do	...do	15	19.12	....	51.50	12.35	3.74	11.61	21.03	100.23	48.62	34.15	....
Pile No. 83	...do	...do	7	....	Treated with creosote and resin. Not analyzed.									....
Pile No. 84	...do	...do	20	8.43	....	13.56	15.78	14.49	19.77	36.13	99.83	....	55.22	....
Pile No. 85	...do	...do	17	13.21	....	19.07	12.39	12.32	17.58	38.14	99.50	18.96	43.71	....
Tie No. 86	E. B. Cushing, Southern Pacific Co., Houston, Tex.	...do	22	*b*19.36 *c*16.14	....	22.53	13.47	22.63	18.58	22.37	99.58	22.53	46.18	....
Pile No. 50	International Creosoting and Construction Co., Galveston, Tex.	...do	29	17.63	1.26	27.60	22.43	31.22	12.02	5.13	99.66	25.41	48.15	....
Pile No. 51	...do	...do	29	17.08	2.18	31.06	18.21	36.04	8.17	4.13	99.79	28.14	41.12	....
Paving block No. 52	...do	...do	34	18.81	.48	26.61	32.06	17.52	8.47	14.42	99.56	....	50.67	....
Paving block No. 53	...do	...do	29	12.44	.68	17.57	18.78	37.52	16.62	8.56	99.73	3.68	53.89	....
Paving blocks Nos. 54 and 55	...do	...do	9	*d*6.07 *e*5.46	9.62	14.41	19.27	41.74	11.23	3.40	99.67	....	....	....
Conduit pipe No. 67	Bell Telephone Co.	Pine	14	8.74	5.08	27.23	10.46	27.68	19.03	9.93	99.41	23.17	14.28	....

*a*Twenty years as a tie and thirteen years as a fence post. *b*Center. *c*Under rail. *d*Paving block No. 54. *e*Paving block No. 55.

GLASGOW AND SOUTHWESTERN RAILWAY, SCOTLAND:

Tie No. 106 taken out of the Main Line February 12, 1905, near Milliken Park; put in during 1889. Creosoted with 2½ gallons of gas-works creosote of 1.010 specific gravity at 60° F.

Tie No. 104 taken out of the Main Line February 6, 1905, near Elderslie Station; put in during 1887. Creosoted with about 2½ gallons of oil to the tie.

Tie No. 113 taken from the Main Line April 16, 1905, near Elderslie Station; put in during 1887. Creosoted that same year with about 2½ gallons of oil to the tie.

Tie No. 109, same history as No. 106.

GREAT WESTERN RAILWAY, HEATH DIVISION, ENGLAND:

Pile No. 118 was in salt water at New Milford 47 years; not decayed, but attacked by Limnoria.

Tie No. 107 was in sidings at Eastern Depot, Swansea, for 42 years.

Tie No. 105 served for 20 years in the Main Line at Hirwain (Vale of Neath), and afterwards was used as a fence post for 13 years.

Memel pile No. 1 was in a tidal river at Loughor for 53 years. Treated with crude coal tar and not analyzed.

Memel pile No. 2 was in salt water at Llanelly Docks for 58 years. Treated with crude coal tar and not analyzed.

LONDON AND NORTHWESTERN RAILWAY COMPANY, ENGLAND:

Ties No. 103 and No. 110 installed in the road for permanent way purposes in 1886; removed February 11, 1905. They were creosoted with blast furnace Scotch oil in 1886.

NORTHEASTERN RAILWAY COMPANY, ENGLAND:

Paving blocks Nos. 88 and 89 removed in perfect condition after being in use at Hull for 20½ years.

Tie No. 114 was under water for 20 years, and afterwards used as a tie under piles of timber in the dockyard for 10 years, a total service of 30 years.

CITY ENGINEER, HULL CORPORATION, HULL, ENGLAND:

Paving blocks Nos. 90 and 91 laid with close joints in 1894; removed in February, 1905, in perfect condition. Paving block No. 92 consisted of three broken blocks laid with open joints in 1892; not decayed when removed in 1905. Treated with creosote and pitch on the outside; not analyzed.

MARYPORT AND CARLISLE RAILWAY COMPANY, ENGLAND:

Ties Nos. 108 and 137 creosoted in 1881, placed in track 1882, and removed in 1905

Tie No. 137 was not analyzed.

HIGHLAND RAILWAY COMPANY, SCOTLAND:

Ties Nos. 2, 3, and 41 were in service in a gravel ballast, damp bed, for 20 years, 20 years, and 22 years respectively. These ties were seasoned two years before treatment and stacked six months after creosoting before being placed in the track.

NORTH BRITISH RAILWAY COMPANY, SCOTLAND:

Tie No. 101 was in the track 21 years; No. 102; 21 years; No. 112, 14 years; No. 100, 14 years (not analyzed). These ties were taken out at different parts of the system.

CLYDE NAVIGATION TRUST, GLASGOW:

Pile No 116 is from the part of the pile which was above high-water level, and was therefore exposed to the air.

Pile No. 111 is from the part of the pile between high and low water. It was therefore exposed to the wash of the water.

Pile No. 117 is from the part of the pile which was always under waiter.

Pile No. 4 is from the part which was buried in the ground.

Pile No. 5 is from the part of a pile above high water; creosoted with 8 pounds per cubic foot.

Tie No. 8 was laid in slag in the year 1883.

CLYDE NAVIGATION TRUST, GLASGOW—Continued.

Tie No. 9 is a part of a Baltic redwood tie laid in 1889. It was bedded in concrete and causewayed over with granite sets. Both of these ties were creosoted with 2½ gallons of gas creosote of not less than 1.010 specific gravity at 60° F.

Pile No. 115 is from the part of Pile No. 5 between high and low water; not analyzed; creosoted with 8 pounds per cubic foot.

NORFOLK CREOSOTING COMPANY, NORFOLK, VA.:

Pile No. 81, section of a creosoted pile put in Santiago Harbor, Cuba, April, 1887; taken out in perfect condition November, 1902.

Pile No. 82, section of a creosoted pile put in Tampico Bay in May, 1891; taken out in perfect condition October, 1902.

Pile No. 83, section of a pile treated with creosote and resin; removed after seven years badly attacked by Teredo.

NORFOLK CREOSOTING COMPANY, NORFOLK, VA.—Continued.

Pile No. 84, section of a creosoted pile put in a drydock at Newport News, Va., May, 1881; removed in good condition October, 1901.

Pile No. 85, section of a creosoted pile in service for 17 years at Newport News, Va.

Tie No. 86 was in the track for 22 years at Houston, Tex.

INTERNATIONAL CREOSOTING AND CONSTRUCTION COMPANY, GALVESTON, TEX.

Piles Nos. 50 and 51 were in Galveston Bay for 29 years.

Paving block No. 52 was in service in the street at New Orleans, La., for 34 years.

Paving block No. 53 was in service in Galveston for 29 years.

Paving blocks Nos. 54 and 55 were in use at Galveston for 9 years. They showed poor service.

BELL TELEPHONE COMPANY:

Conduit pipe No. 67 was in service as conduit at Philadelphia, Pa., for 14 years; removed in perfect condition to make extensions of service.

Approved April 1, 1907.

JAMES WILSON,

Secretary.

Wood Distillation

BY W. C. GEER, EXPERT.

[NOTE.—The Forest Service has received many inquiries about the commercial distillation of hardwoods and softwoods and the quantity of the products obtained. It has been impossible to answer these inquiries by letter as fully as desired, and the growing need of a popular publication which would briefly state a few facts on wood distillation has been strongly felt. For this reason this circular has been compiled. It is not intended to be technical in nature or to contain the results of original investigations, but rather to furnish a few facts concerning the wood distillation industry as it now stands in this country. Circulars of a more technical character and dealing with concrete problems in wood distillation will follow.]

INTRODUCTION.

There are two distinct processes for obtaining valuable products from wood by distillation—destructive distillation and steam distillation. In the destructive process the wood fiber is broken down and new compounds are formed, but in the steam process this is not properly the case. In both processes volatile compounds of the wood are vaporized.

In destructive distillation heat is applied below the wood-containing vessel, which has a comparatively small pipe as its only outlet. The heat vaporizes the volatile compounds, such as water and turpentine, and breaks down the nonvolatile compounds, such as cellulose and the wood gums; it forms a number of new compounds, usually of a simpler chemical nature, and these in turn are vaporized with the water and turpentine, leaving a residue of charcoal. The decomposition of the wood in this process is exceedingly complicated and is not yet fully understood.

In steam distillation, which is much simpler, the wood is chipped and placed in a closed receptacle into which steam is blown from a boiler, and the volatile compounds which are not chemically united with the rest are vaporized and carried out of the retort with the steam. Though in practice the wood is often so much overheated that the wood fiber is slightly decomposed, and though it is quite possible to carry the overheating so far that the process becomes one of destructive distillation, it is nevertheless true that "steam distillation," as the term is technically used, signifies the

separation of volatile products from wood with, at most, but little decomposition of the wood fiber.

With both these processes the vaporized compounds after leaving the retort pass through water-cooled tubes, where they are condensed into the crude liquors which after refining yield marketable products.

Different woods give different marketable products after distillation. Thus, the hardwoods—beech, birch, and maple—yield acetate of lime, wood alcohol, and charcoal, and longleaf pine yields turpentine, tar, pine oils and charcoal. This difference in the products is due to the fact that pine woods are resinous, while hardwoods are nonresinous. From the point of view of products, therefore, it is necessary to distinguish between the kinds of wood used, as well as between the distillation processes.

DESTRUCTIVE DISTILLATION OF HARDWOOD.

Hardwood distillation has been an established industry in the United States for a number of years. The products already mentioned are wood alcohol, charcoal and acetate of lime, each of which has important uses. The plants are located in the northern part of the United States, where, except for the Appalachian hardwood belt, the hardwoods are most common.

The woods used are largely beech, birch, and maple, with the last preferred. The wood is cut into cordwood lengths and allowed to season for a year. According to the best information, the amount of the products obtained from green wood and from ordinary dry wood is not different, cord for cord, but the higher water content of green wood dilutes the distillate and necessitates more fuel for the carbonization. Excessive seasoning will doubtless reduce the yield of valuable constituents. Body wood is better than slab wood. Very small wood, such as thin edgings, carbonizes so rapidly that it must be mixed with larger pieces. The problem of the destructive distillation of sawdust has not yet been satisfactorily solved.

APPARATUS.

Wood is heated or carbonized in three forms of apparatus: *(a)* In brick kilns, *(b)* in retorts, *(c)* in ovens.

The charring of wood is a process as old as civilization. In the early days the wood was charred under sod in the old charcoal kiln, which has been a familiar sight over a good part of the world. The modern charcoal kiln is so made that valuable vapors are condensed from the smoke, which in the old-fashioned kiln escaped

into the air and were wasted. Kilns are now mainly used to produce charcoal for blast furnaces for pig iron. They are made of brick, with a circular base, and divided approximately into two semi-circular sections. They hold each about 50 cords, and are charged and discharged by hand. The vapors are carried off into condensers, where the condensable ones are liquefied.

The name "retort" is given to a small form of cylindrical vessel holding about three-fourths of a cord. The retorts are set horizontally in brickwork, in pairs, each pair forming a "battery," and heated from beneath. They are filled and discharged from a single door in front, which can be tightly fastened. The top of the battery is often tiled and serves as a drying floor for acetate of lime. The condensers are of copper, and are cooled by water. A "run," from charging to recharging, takes twenty-four hours.

The invention of the "oven" form of carbonizing vessel marked a distinct forward step in wood distillation. Oven kilns are made large enough to hold from two to four cars, which are run in on tracks, each loaded with about 2 cords of wood. They are usually fired separately, and the vapors pass over into the condensers either at the side or at the end. In other respects they resemble the "retorts."

PRODUCTS.

Four crude products are obtained from each of these forms of carbonizing vessels: (1) Charcoal, which remains in the vessel; (2) a noncondensible gas, which is carried off by suitable pipes; (3) an aqueous liquor known as "pyroligneous acid;" and (4) wood tar, which is condensed with the pyroligeneous acid.

The charcoal is cooled differently in the case of each distilling vessel, though in all cases it is cooled for forty-eight hours. With kilns, it is allowed to cool before being removed; with the retorts, it is shoveled into drums or cans and sealed from the air; and with the ovens, the loaded cars are run out and closed in large coolers, which are similar in form to the ovens.

The gas from the kilns is piped back into the kiln furnaces, where it serves to carbonize the wood. The gas from retorts and ovens is burned under the boilers or under the retorts.

The pyroligneous acid and the tar run off together from the condensers into vats, where the tar settles. The pyroligneous acid is reddish brown in color and has a strong, characteristic, burnt-wood odor. The tar, when in thin layers, is dark brown in color, and has a bad odor. These two liquid products are refined by processes

which in general are the same for each of the three forms of carbonizing apparatus. The processes differ somewhat, however, at the different plants.

Dissolved in the tar are some of the valuable compounds of the pyroligneous acid, while dissolved in the pyroligneous acid are some tarry bodies. Both liquids are distilled in order to concentrate the valuable substances, which are chiefly acetic acid and methyl, or wood, alcohol. The concentrated liquid containing the acetic acid and methyl alcohol is neutralized with lime and distilled from a "limelee" still, giving (1) a residue which upon evaporation yields gray acetate of lime, and (2) a distillate which upon refining yields the various grades of wood alcohol.

Some plants obtain a crude, brown, evil-smelling wood alcohol, of 82 per cent. strength, which is sent to a refinery for further treatment; others obtain a 95 to 99 per cent. product without color or unpleasant odor. Wood alcohol is ill-smelling only when impure as a result of incomplete refining.

Oven and retort plants which produce alcohol no purer than 82 per cent. secure about the following average yields from wood distillation per cord of wood:

Charcoal	45 to 52 bushels
Gray acetate of lime	180 to 225 pounds
Wood alcohol, 82 per cent	8 to 10 gallons

The lack of chemical supervision at the works makes statements of yield a little confusing, since wood alcohol and acetate of lime are variable in quality and the number of gallons and pounds may therefore actually represent products of quite different composition.

Kiln plants obtain about the following yield per cord of wood:

Charcoal	45 to 52 bushels
Acetate of lime	90 to 150 pounds
Wood alcohol, 82 per cent	4 to 6 gallons

USE OF PRODUCTS.

These compounds have a variety of uses, which may be briefly mentioned. Charcoal is used in blast furnaces, for the production of pig iron, in copper and sugar refineries, in the production of gunpowder, for fuel, etc. Wood alcohol is sold under a variety of trade names, such as "columbian spirit" and "colonial spirit." It is most widely used as a solvent in the production of shellacs and varnishes. It is also used in hat making, in perfumery, in the coal-tar dye industry, in manufacture of formaldehyde, and for mixing

with grain alcohol to produce "denatured" or "industrial" alcohol. The acetate of lime is a gray, finely crystalline body, which is used in the manufacture of wood vinegar, acetic acid, many commercial acetates, acetic ether, acetone, and other products. (From the acetone may be produced iodoform and chloroform.)

A number of receipts for the preparation of denatured alcohol have been recently authorized by Congress and established by the Commissioner of Internal Revenue, so that denatured alcohol, with its due admixture of wood alcohol, is now a market article. The wood distillation plants now in existence in the United States are able to produce probably 30,000,000 gallons of wood alcohol annually.

Denatured alcohol is now a competitor of wood alcohol. At present the producers and refiners of wood alcohol are in suspense as regards the extent of the consumption of the product for denaturing purposes.

STEAM DISTILLATION OF HARDWOOD.

Several species of hardwood are distilled by steam in order to obtain valuable essential oils. Sweet birch, for example, yields "oil of wintergreen," an oil used in medicinal preparations. No thorough study has yet been made of this division of the subject, but it is known that a small industry is supported.

DESTRUCTIVE DISTILLATION OF YELLOW PINE.

The destructive distillation of yellow pine is carried on in the Southern States, where the distillation plants are so widely scattered that a statement of the location by States would mean but little.

The wood generally used is that of longleaf pine, from which turpentine and rosin are mainly obtained. At some plants, however, longleaf pine, shortleaf pine, Cuban pine, and others are indiscriminately used, but for the best results longleaf and Cuban pines are selected. The most valuable material is wood rich in resinous contents, or "fat," in which lightwood and stumps rank first, wood immediately under the "box faces" next, and slabs and other mill refuse last. Pine sawdust is not used for destructive distillation.

APPARATUS.

Iron or steel retorts are used, varying in capacity from 1 to 4 cords. They are either vertical or horizontal. The vertical retorts have their long axis upright, and are set singly in brickwork with suitable flues, usually with the openings for charging and discharg-

ing at the top and bottom. The firebox below is at one side, so that the heat goes around the outside of the retort itself. Few of these retorts are now in use.

The horizontal retorts are similar to those used in hardwood distillation. Though they differ as to form, all are cylindrical steel vessels set in batteries in brickwork and are charged and discharged through doors at one or both ends. The gases escape through pipes to copper condensers. The firebox is sometimes constructed to fire two retorts at a time, though usually but one.

PRODUCTS.

Though there are a number of methods which differ somewhat in results, the five products usually obtained are: (1) Charcoal; (2) a noncondensible gas; (3) light oils, which are often taken in two fractions, one of which is a crude turpentine; (4) tar, and (5) pyroligneous acid. At some plants the light oil vapor, which volatilizes easily, is led off into condensers with the gas and pyroligneous acid, while the tar, which is heavier, is drawn off at the bottom; at others, the entire volatile product is driven off through a pipe at the top and, after passing through the condenser, is separated into the crude turpentine and tar fractions.

There is no more uniformity in heating methods than in the form of the retorts. The run is thirty-six or forty-eight hours, or longer. Charcoal which is to be sold is cooled in the retort, and that which is to be used for fuel is drawn hot and sprayed with water to prevent fire. The gas is allowed to run to waste or is burned under the retorts and boilers.

The pyroligneous acid from hardwoods contains the most valuable products, but that from pine, which has a strong odor and a reddish-brown color, is of such different composition that very little is done with it. The yield from a cord of pine wood is, according to the most widely accepted figures, not more than 3 gallons of 82 per cent. wood alcohol and about 70 pounds of brown acetate of lime. The extraction of wood alcohol from pine wood is not at present on a commercial basis, and at the majority of plants the pyroligneous acid runs to waste.

The crude turpentine is a dark red oil with the bad odor associated with products of destructive distillation. After proper fractional distillation, it yields for market a nearly colorless turpentine, which has a distinctive odor.

The tar is sometimes refined far enough to produce a good quality of retort tar and to yield oils which, with the heavy distillates

from the crude turpentine, make disinfectants, wood creosote, and a number of market articles.

The refining processes, which are largely secret, are not the same at all plants, while the products sold are far from uniform.

Since few plants operate under the same conditions, and since a number of products may be obtained from the tar and crude turpentine, it is difficult to estimate the amount of products obtained from yellow pine. Moreover, the wood itself varies widely in resinous content. Heavy, rich "lightwood" contains the largest quantities of turpentine and other oils, whereas other kinds of "lightwood" may yield but little. Sapwood yields the least. The following table shows as nearly as practicable the ordinary yields per cord of wood obtained in practice by the destructive process:

Refined turpentine	7 to 12 gallons
Total oils, including tar	50 to 75 gallons
Tar	40 to 60 gallons
Charcoal	25 to 35 bushels

USES OF PRODUCTS.

The turpentine is used as a second grade, inferior to gum turpentine. There are no recognized grades of destructively distilled turpentine, and the composition of the turpentine from different plants is not uniform. Formerly it was poorly refined; it is now made practically colorless. In the refining, certain heavy oils are obtained, which, when combined with similar heavy oils from the tar, are made into "pine oils," used as disinfectants, paint dryers, wood preservatives, etc. One of the uses for the tar is cable coating. The uses of the acetate of lime, in this case "brown acetate," have already been mentioned. The charcoal is burned at the plant or sold for fuel. The pyroligneous acid in its crude form is occasionally sold, although most of it goes to waste.

Several causes have led to many failures among plants of this kind. One of these was bad management. Men engaged in the business, without training or a knowledge of the market, expected an immediate demand for the products. Another cause was the use of inferior retorts, which in many cases were made of thin steel and so were quickly burned out. A third was lack of perseverance when difficulties arose.

STEAM DISTILLATION OF YELLOW PINE.

The plants which distill wood by the seam method are located in the yellow pine belt. In general, the wood is the same as that used for the destructive distillation of yellow pine, but is separated into

classes. Steam plants use the richest wood that can be secured, since turpentine is the only valuable product, although the wood after extraction is used for fuel. The wood is divided into three classes: (1) The rich "lightwood," of which several grades are used; (2) stumps, which are also rich in turpentine; and (3) sawmill waste, which includes sawdust, butt cuts, and slabs. All wood must be "hogged" into chips before it is placed in the retorts.

APPARATUS.

Both vertical and horizontal retorts are successfully used. But the wood is treated by two different methods, one using superheated steam under low pressure and the other saturated steam under higher pressure.

With superheated steam a vertical retort is used, and the steam, before entering the retort, passes through a superheater, which raises its temperature high enough to readily volatilize the turpentine. From the condensers the distillates run into a separator.

For saturated steam several sorts of retorts are used, and the steam enters them directly from the boiler. There are a number of patented devices, the most important differences in which have to do with methods of charging and discharging. The fundamental idea, however, is to maintain a sufficient pressure of steam, throughout the run, to facilitate rapid extractions. A separator is used, as with superheated steam.

PRODUCTS.

The products of both processes are crude turpentine and water, in a separator tank, and chips left in the retort. The turpentine, which is lighter than water, floats on the surface and is easily drawn off, ready for refining. The chips, after drying a short time in the air, are suitable for fuel.

In order to obtain a market grade of turpentine, the crude product should be refined by distillation with steam in a copper still. As it comes from the retort its color is slightly yellow.

There is the same variety in methods used as in other kinds of wood distillation, and consequently the same lack of uniformity in the products. Much remains to be learned as to the best method of refining turpentine so as regularly to secure the best grades.

The amount of turpentine obtained from steam distillation varies widely. The wood itself varies greatly in richness. A conservative average per cord is given in the following table (the difference between stumps and "lightwood" is slight enough to be disregarded):

Lightwood:		
Refined turpentine	10 to 15	gallons
Heavy oils	1 to 3	gallons
Sawdust:		
Refined turpentine	2 to 4	gallons
Heavy oils	½	gallon

The refined turpentine is of reasonably uniform quality, is nearly colorless, has an agreeable odor, and has a fair market at a price somewhat below the market price for gum spirits of turpentine.

COMPARISON OF METHODS.

Comparing the steam methods with the destructive methods, although there is room for difference of opinion, it would seem that the steam distillation is open to the wider development. The successful destructive distillation plants are those which are run by men who have remained in the business long enough to establish their processes and methods and the markets for their products. Turpentine, the leading product, is probably produced less expensively by the steam method, and the steam apparatus necessary to handle a given quantity of wood per day, say 50 cords, is easier to operate.

There have been fewer failures in steam distillation than in destructive distillation, perhaps because it is of more recent development, and because those promoting the enterprises have been able to profit by the mistakes of their predecessors. Yet many operators have failed, mainly because they had not familiarized themselves with the fundamental principles controlling the successful construction and operation of a plant.

The figures on pages 6 and 7 are not intended to compare yields by destructive and steam distillation from the same grade of wood, but simply the yields obtained by the two methods under actual conditions, where, in point of fact, very different grades of wood are used.

There is but scanty published information on the properties of the turpentines produced by these two processes in America, or on their actual value in the paint and varnish business. Up to the present these turpentines are merely competitors of "gum spirits."

Approved: JAMES WILSON, secretary of Agriculture.
Washington, D. C., August 19, 1907.

Miscellaneous News Clippings

Growing Forest Timber

FROM FARMERS' GUIDE.

In this article I shall try to prove to Guide readers that the time has arrived when we should plant timber; that the most profitable tree to plant, all things considered, is the upright growing catalpa speciosa; that it can be grown at the rate of five tons per acre per year; that it is worth more per ton for posts than the average farmer gets for his timothy hay delivered at the railway; that the trees can be set as easily as tomatoes and cultivated as easily as corn for the first two or three years, after which no further cultivation is required.

Twenty-five years ago I sent to E. E. Barney, of Ohio, for his booklet on catalpa culture. At considerable cost of time and money he had gathered the facts contained regarding this valuable tree. He urged its planting by railroads, farmers and others in preference to anything else. So anxious was he for the future timber supply that he sent his booklet gratuitously, postage paid, to all who asked for it.

At the St. Louis exposition there was a catalpa exhibit. In it was a post that had been in constant use, and in a good state of preservation eighty-five years and a railroad tie thirty-two years. Also beautiful furniture and a section of a magnificent passenger coach, the inside finish of which was equal to Honduras mahogany.

Those of my readers who have had occasion to build anything recently or to buy fence posts or telephone poles need not be told how almost prohibitory are present prices. A lumber dealer in Crawfordsville prices cedar posts from Tennessee, five inches in diameter at the butt, at forty cents each and end posts nine inches in diameter at $3. I recently saw at Greencastle a car load of forty interurban poles from Idaho the freight on which was $400, or $10 each.

Twenty-five years ago we thought we had timber enough for centuries, so not many acted on Mr. Barney's advice, but the few who did are now reaping a golden harvest.

In my travels over the State in farmers' institute work I have met with and talked to the owners of some of these groves and with a tape line I have carefully measured hundreds of trees, and I find that on good land not too closely set and properly cared for, they

will add an inch in diameter for every year of their growth up to, say, twenty years. The illustration herewith is a reproduction from a photograph of a view in one of these groves. This grove was set in 1883, the trees only 5½ by 6 feet apart. It consists of 1.68 acres and is on rather poor land. It was cultivated two years, pruned for a few years and partially thinned when large enough for posts. The number of trees originally set was 2,700 (twice too many) and there are now standing 1,500, 1,200 of which are large enough for posts. The owner, I was told, refused $800 for them three years ago. I measured the trees in the five north rows of this grove one foot above the ground and they averaged as follows, after deducting one inch for bark. The first or outside row of thirty-five trees averaged 12.6 inches in diameter; the second row 8.7 inches; the third row 8 inches; fourth row 8.1 and the fifth row 8.25 inches, and they were fifty feet high and many of them straight as gunbarrels and would make five post cuts to the tree. Some of the trees in the outside row measured nineteen inches in diameter and one measured twenty.

Now while this is one of the best groves in the state, yet the trees were too closely set and too tardily thinned. This is proven by the much larger size of the outside rows. As near as I could estimate the largest trees would make twenty-five posts each, and were they as straight and tall as the inside trees, would make such interurban poles as I saw at Greencastle, the freight on which was $10 apiece.

There are a number of catalpa groves of known age in Ohio, under the watchful eye of the officials of the state experiment station. According to their observation the trees should not be set closer than 5 by 8 feet apart, and thinned as soon as large enough for posts, which on good land will be in from seven to eight years. The first thinning should take out every other row both ways. Set 5 by 8 feet there are 1,080 trees per acre. Taking out every other row each way (810 trees) leaves 270 trees, standing 16 by 10 feet apart. In five years more another 100 should come out, leaving 170 trees to grow to the end of 20 years, when they should average 20 inches in diameter. Now let us figure a little and see if we can find about what our acre will be worth at present prices of posts, remembering that for fine finishing work or veneer they would be worth much more.

Instead of 30 or 40 cents each, the retail prices of posts in Indiana now, we will call the price 20 cents. At the first thinning we took out 810 trees; at one post each they are worth $162. The second thinning will make 1,600 posts, worth $320. The final cutting of the 170 trees figures something like this: Each tree will

make seven post cuts, ranging in number from 16 in the butt cut to one in the top cut. It will make 29 first-class, four second-class and one good end post, making the tree worth $9.40. Multiply this by 170, the number of trees, and we have $1,598. To this add $482, the value of the other cuttings, and we have a—well, cut it in two in the middle and it will beat timothy hay. At the freight charge on the Greencastle poles, it makes the 170 trees alone worth $1,700 an acre. This equals an annual growth of $85 an acre.

To show that twenty inches is not too radical a claim to make for catalpa growth note the illustration of cross section of tree. As one can readily see by the annual growths, shown by the rings, the trees from which I cut this section was 19 years old and 24 inches in diameter. It also shows that for every four years of its growth it added about five inches to its diameter. During the four years from the 12th to the 16th it added five and one-fourth inches.

Railway authorities estimate that they will need five billion ties in the next ten years, and that to supply them and the telegraph poles and the fence posts for their right of way for the same period will require the timber from five million acres of heavy forest.

Locust is a splendid tree, but it has three objections not possessed by the catalpa; it sprouts too freely from the roots, the catalpa sprouts from the stump only; it is so hard when seasoned and splits so easily that it will not hold a spike as a railroad tie, and last, though not least, whole plantations are sometimes killed by the borers.

There is one unfortunate thing connected with the catalpa, and that is the difficulty of getting the true speciosa. The seeds of the low branching catalpa bignonioides which we see along the streets in our towns are very like the others and many nurserymen have in the past and are now sending out such trees for the true speciosa.

As forest products are steadily advancing in price it would seem that every farmer ought at least to grow his own posts. Suppose you plant ten acres and cultivate the balance of your farm a little better. Your bushels and tons would not be much reduced, and see what you will have in timber twenty years from now.

With no cultivation after the third year the trees just grow, no worrying about wet or dry or hot or cold weather and no labor problem, as your harvest is in the winter when labor is cheap and easy to find.

Nor is this all: In the grove above described is a rich blue grass carpet of living green, and has been for years.

Putnam County, Ind. L. A. STOCKWELL.

Indiana and Its Industries

INDIANAPOLIS STAR, OCTOBER 28, 1907.

In no other industry has Indiana's showing declined as rapidly as in that of the hardwood lumber industry. It has been the rule that other Indiana industries have advanced, but the lumber industry has proven an exception to the rule. Figures compiled on Indiana's hardwood lumber supply and the production by the lumber industry show that the maximum production has been reached. Softer lumber materials have not declined as rapidly as the hardwood lumber, but their day is coming. Enormous quantities of lumber are required each year in Indiana as well as in other States for railroad ties, telephone and telegraph poles, piles, fenceposts and fuel, as well as wood for lumber making. A great amount is wasted in lumbering and manufacture. Because of the rapid clearing of the forests in this State it is necessary at this time to bring most of the railroad ties and telegraph poles into the State. The amount of standing hardwoods is uncertain, as no census has ever been taken of the standing timber and there have been but very few estimates of Indiana's supply. The largest estimate sets the figure at eight billion feet. It is estimated that Indiana's lumber supply is being exhausted at the rate of 30,000,000 feet per year. This would mean that Indiana's supply will last about twenty-four years more.

Conditions during the past year, according to lumber dealers, suggest no reason for increasing this estimate. A distinct difference exists between the softwood and the hardwood situation, there being soft woods in many parts of the State still accessible. However, when the supply is gone there will be no other source upon which to turn. Only within the last eight years have prices begun to reflect the dwindling supply, though the immoderate cutting away of this resource has been going on for decades.

Considering the impoverished supply and the tremendous demands on the part of all industries for timber, lumber men say that there is nothing surprising about the increase in prices on hardwood lumber, which seem to have failed to keep pace with the increased prices on soft lumber. This is considered rather re-

markable, in view of the shorter supply, but is probably due, lumber men say, to the fact that soft woods forming the main bulk of the lumber supply have led in establishing prices. The high price on both soft and hard woods is taken to indicate, lumber men say, that the industry has reached rock bottom and requires every sound piece of hardwood lumber that can be put upon the market.

Several great industries in Indiana use hardwood timber mainly or almost exclusively for their raw material. Notable in this list are hardwood lumber manufacturing plants, the cooperage, furniture and vehicle industries and the industries engaged in the manufacture of musical instruments, coffins and small wooden ware. All of these industries would suffer greatly and some would fail entirely upon the exhaustion of the hardwood supply. Other industries, such as the manufacture of agriculture implements, freight and passenger cars and boxes and crates, use immense quantities of hardwoods.

Hardwood lumber manufacture affords an example of the damage that has already been done. It has been shown how hardwood lumber production in Ohio was cut down over one-half between 1899 and 1906. In Indiana during the same period the lumber industry fell from the third to the eighth place; the value of products increased 27.1 per cent.; the number of wage earners decreased 42.6 per cent. and the wages paid decreased 36.6 per cent. Indiana lumber manufacturers were among the first to feel the blight of the exhausted timber supply. When the local supply ceases this industry must stop. Most industries which now use hardwoods can go on, however, by bringing their supplies from a distance. It is only with the failure of the entire supply that they are damaged.

In much the same way the cooperage industry must be near the forests. Slack cooperage employs a great number of hardwoods. Tight cooperage makes use of the best grades of white oak almost exclusively. The pressure of lack of timber is already heavy on this industry everywhere in Indiana. If the oak supply should fail, the tight cooperage industry will cease largely, for as yet very little progress has been made toward securing substitutes for the oak keg and barrel.

The manufacture of furniture probably demands more hardwood than any other industry and employs it almost exclusively as raw material. According to lumber men it is apparent that the industry uses 20 per cent. of the hardwood production. Failure of the hardwood supply may exterminate the furniture making

industry in Indiana eventually for the reason that the people demand hardwood furniture and will accept but little of any other kind.

As in furniture, hardwood is the chief material used in the manufacture of musical instruments, especially pianos and organs. Maple, poplar, elm, oak, chestnut and basswood are most largely used. Foreign woods are used only for veneers.

No industry stands in a more threatened position, so far as the limited timber supply is concerned, than the vehicle-making industry. The building of wagons and carriages requires the best of hardwoods, now obtained with extreme difficulty. Vehicle manufacturers and forestry men assert that the hickory supply of the entire country can last but ten years longer. Attempts to substitute other woods or other materials for hickory in manufacturing vehicles have failed largely. Metal has, to some extent, taken the place of wood in farm implements, but surprisingly large quantities of hardwood are still used. Steel is being employed more and more in the manufacture of freight and passenger cars. Half of the two million cross ties used annually on the railroads of Indiana are hardwood ties. Although there are many substitutes for the wooden cross tie, they have not been entirely as acceptable to the railroads as the wooden cross tie.

The supply of hardwoods in both Indiana and Ohio is practially exhausted. Indiana's hardwood supply has fallen from 976,000,000 feet produced in 1899, to 446,000,000 feet in 1906. Together with Illinois, Ohio and Indiana produced 25 per cent. of the hardwood in 1899. In 1906 they produced only 14 per cent. These States can never regain their lead or even maintain the standing they have. The land which bore this timber, as fast as it was cleared, has been turned into agricultural use, for which most of the Hoosier soil is well suited. The improved farm lands of Indiana increased 10.4 per cent. between 1890 and 1900. Some waste land will continue to turn out timber, but not enough to have any considerable effect on the State's hardwood supply.

Figures furnished by the United States Department of Agriculture show that the wooded area in Indiana is 6,912,000 acres, of which 2,000 acres belong to the State and 6,910,000 are private unreserved public forests.

Many farmers of the State are planting groves of forest timber, so as to replace the waning supply. Catalpa trees are being planted for ultimate use as fence posts and cross ties. L. A. Stockwell of Putnam County owns a catalpa grove near Greencastle. In

a recent communication he discusses the growing of trees to replenish the forest supply. He says in part:

"Instead of 30 or 40 cents each, the retail prices of fence posts in Indiana now, we will call the price 20 cents. At the first thinning we took out of our grove 810 trees; at one post each they are worth $162. The second thinning will make 1,600 posts, worth $320. The final cutting of the 170 trees figures something like this: Each tree will make seven post cuts, ranging in number from sixteen in the butt cut to one in the top cut. It will make twenty-nine first-class, four second-class and one good end post, making the tree worth $9.40. Multiply this by 170, the number of trees, and we have $1,598. To this add $482, the value of the other cuttings, and we have a—well, cut it in two in the middle and it will beat timothy hay. At the freight charge on the Greencastle poles, it makes the 170 trees alone worth $1,700 an acre. This equals an annual growth of $85 an acre.

"To show that twenty inches is not too radical a claim to make for catalpa growth note the illustration of cross section of tree. As one can readily see by the annual growths, shown by the rings, the tree from which I cut this section was 19 years old and twenty-four inches in diameter. It also shows that for every four years of its growth it added about five inches to its diameter. During the four years from the twelfth to the sixteenth it added five and one-fourth inches.

"Railway authorities estimate that they will need 5,000,000,000 ties in the next ten years, and that to supply them and the telegraph poles and the fence posts for the right of way for the same period will require the timber from 5,000,000 acres of heavy forest."

Statistics compiled by the State Bureau of Statistics show that the carriage and wagon making industry in 1905 ranked sixth in Indiana, on a basis of products, yet Indiana ranked second that year among the States of the Union in the production of carriages and wagons. South Bend and Indianapolis are the most important centers of production, the combined output of these two cities representing 52 per cent of the entire output of the State. The increase in family and pleasure carriages over 1900 is one of the striking facts in this connection. The increase over 1900 is 26.3 per cent, or a total number of 37,228 carriages. There was a decrease in the number of business wagons manufactured.

The following comparative tables have been arranged by the State statistician from data collected relative to the manufacture of furniture and lumber in Indianapolis from 1900 to the year 1905—the latest figures at hand.

COMPARATIVE TABLE OF FURNITURE MANUFACTURERS—1900-1905.

	1900.	1905.	Per cent. Rate of increase
Number establishments	22	34	54.5
Capital invested	$1,366,919	$1,812,058	32.6
Salaried officials, clerks, etc.	$105,810	$159,799	51
Number salaried officials, clerks, etc.	119	149	25.2
Cost of material	$806,568	$1,052,114	30.4
Products, including custom work	$1,685,827	$2,528,238	50
Wage earners	1,182	1,629	37.8
Wages	$456,644	$764,399	67.4
Miscellaneous expenses	$127,250	$298,704	134.7

COMPARATIVE TABLE OF MANUFACTURE OF LUMBER—1900-1905.

	1900.	1905.	Per cent. Rate of increase.
Number establishments	23	33	43.4
Capital invested	$1,021,708	$1,549,871	51.6
Salaried officers, clerks, etc.	$65,769	$114,556	74.1
Number salaried officials, clerks, etc.	57	112	95.9
Cost of material	$801,196	$1,772,649	121.2
Value of products	$1,588,797	$2,667,730	64.8
Wage earners	780	879	12.7
Wages	$326,576	$452,094	38.4
Miscellaneous expenses	$162,502	$118,263	27.1

News clipping from Pennsylvania, showing the trend of the forestry work in that State, and from which comparison with Indiana forestry may be made:

The work of the State Department of Forestry has become so well advanced that revenue from the timber on the forestry reservations will probably be realized within a few years. Deputy Forestry Commissioner Williams is of the opinion that within twenty-five years the net proceeds from the sale of timber and other products of the reservations will prove to be a very substantial sum.

Considerably more than 700,000 acres of forestry reservation are now owned by the State and by the end of the present calendar year the total will be increased to at least 800,000, unless the plans of the Forestry Department entirely miscarry.

A REMARKABLE SHOWING.

This work is the most remarkable because actual purchase of land for reservation purposes was not begun until 1898, although preliminary work began five years prior to that time.

Plans for scientific prosecution of the work on the reservations came to a head in 1903, the year before Dr. J. T. Rothrock retired as commissioner, when the State Forestry Academy was established at Mont Alto. Robert G. Conklin, of Columbia, son of Robert J. Conklin, now commissioner, but at that time deputy, was the first student. The academy course is three years; two classes have been graduated from the academy, giving the State eleven young foresters who are now at work on the reservations.

These foresters carry out on the reserves the ideas in which they have been instructed at the academy.

TO INCREASE THE PLANTING.

Tree planting has been conducted on a somewhat limited scale on the reserves ever since the State began to purchase land, and this work will be materially extended in the future. Many thousands of young trees have been set out, but the annual plantings will be numbered by the million before long. Nurseries at Mont Alto and Greenwood, Huntingdon county, are prolific of young trees and another nursery at Tioga county adds materially to the output. All kinds of trees are bred, white pine being a leader, and the sprouts are set out in the reserves best adapted to receive them.

So far the planting has been pursued with the main idea of protecting the watersheds, but when the work of the department is further advanced the foresters will set out trees with a view of obtaining the best possible commercial results.

Culling inferior timber is a question of only a few years—timber of use mainly for cordwood, or for the cheaper lines of furniture and building. The present generation, however, will in all probability witness the time when a sawmill will be a feature of each reserve and the State will be in business actively marketing timber of all kinds.

The Timber Supply

Louisville Courier-Journal, November 6, 1907.

Mr. Gifford Pinchot, the Government forester, says that at the present rate of cutting, the timber supply in the United States, on Government reserves, and private holdings, will be exhausted in twenty years.

Mr. Pinchot is a man whose cool judgment and discretion give him a high rank. For all that his judgment may be too pessimistic. If, however, he is right, the consumption will necessarily diminish, and that speedily, so that the actual exhaustion of supplies will no doubt be postponed to a date beyond that which he fixes.

Nevertheless the situation is very serious. The destruction of our timber is certainly going on at a tremendous rate. Provisions to renew it have been made, but on a scale so small comparatively that they afford no prospect of a continuance of the supply.

The consequences of the exhaustion of our supply of timber are calculated to be of the gravest character. Putting it at not more than twenty years is calculated to make it almost a present situation. If the supply is so restricted and the consumption so great, immediate steps are indispensably requisite to avert the disaster.

There are two methods which appear on the surface to be demanded. The first is to do what can be done to stop the immense consumption of our timber. When the supply is all gone some other means must be found to furnish material for the purposes for which timber is now used. But it is obviously unwise to postpone this until the timber is exhausted. The substitute material should be found now, and the work of applying it should be at once commenced. The greater use of iron and steel instead of timber is one resource, and there has been an immense increase in this respect, but apparently without sparing the timber. Our production of iron has increased phenomenally, but still the timber waste goes on.

The natural resources of this country have been so great that until recently the prospect of their exhaustion was not seriously entertained. We had gone on cheerfully reducing them as if they

were inexhaustible. In recent years the note of warning has been sounded, but it has had little practical effect. The waste goes on, and at an accelerated rate of speed. The population has greatly increased, and the demand on our natural resources has correspondingly been augmented. The greed of gain has dictated the destruction of our forests, without any reference to what is to be done when they are all gone.

Attention is naturally directed to the Dominion of Canada, where there are immense supplies of virgin timber. But our tariff laws continue to offer a premium for the destruction of our own timber. If these were changed there would be less motive for the so rapid destruction of our timber, and in the West there has been a very decided sentiment in favor of a change in the laws. The difficulty in doing this is, of course, pretty well understood, but the creation of an overwhelming public sentiment in its favor is not impossible.

The second point to be noticed is the need of reforesting the numerous areas that have been denuded of timber. This is a slow process, and it cannot be too soon begun in real earnest. For years we have had a good many people who insisted on the need of renewing the forests that had been destroyed. The planting of trees has been recommended, and to some extent accomplished. The point is that the work has not assumed such proportions as to supply the waste in any tolerable degree. A more general, a more concerted effort to renew the supply of timber is not only necessary, but it is requisite that it be entered upon at once.

This is not altogether a work for the Government. Mr. Pinchot says that one-fifth of the forest area is in the Government reserves, but as the privately-owned timber lands are better than those of the Government, the Government does not own one-fifth of the timber supply. The Government may make an effort to preserve its forest areas, but it is known that attempts in this direction are subject to great difficulties. But however these efforts may succeed, it is necessary to bring to bear upon private owners such influence as may lessen the destruction of the timber. How this may be done is a hard question. So long as such destruction is enormously profitable it will continue, quite in disregard of the evil consequences that are threatened. It would seem proper that both the Federal and State Governments should make an effort to diminish the waste. Certainly there ought not to be laws which offer a premium for the destruction of the timber.

The proposed conference at Washington with reference to the ex-

haustion of our national resources ought to do something to awaken public sentiment upon the evils of the destruction of the timber supply. It is given out that the forest reserve will ask Congress for more money and more men to push the work of reforesting the denuded timber lands. This seems to be well advised, in a campaign to overcome the objection of the House machine to its passage. By saving the hardwood supply, and guarding against an annual increase in damage by flood in winter and drought in summer, two birds may be killed with one stone. Moreover an important forest reservation east of the Mississippi would serve to further educate the East as to the advantages of saving natural resources, and it would be less difficult for scheming Western politicians to convince members of committees in Congress that the Government oppresses new States when it curtails the activity of the timber grabbers.

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